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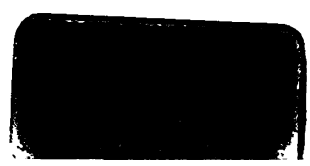

MINING METHODS IN EUROPE

MINING METHODS IN EUROPE

WRITTEN AFTER A VISIT TO MANY OF THE METAL AND COAL MINES OF GREAT BRITAIN, FRANCE AND GERMANY

BY

LUCIUS W. MAYER, E.M.

ILLUSTRATED WITH DRAWINGS AND PHOTOGRAPHS FOR THE MOST PART BY THE AUTHOR

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To

HIS SISTER

THIS BOOK IS FONDLY DEDICATED

BY THE AUTHOR

PREFACE

THIS volume describes more or less distinct and often extraordinary systems of mining practised in various countries of Europe. Its presentation, by an American, to those interested in mining, follows considerable travel abroad, consequent to a thorough study of American and European literature treating on the subject of mining methods.

There is hardly a feature in the art of mining on which more depends than the method of underground attack, and this work was incited by the apparent lack of literature on the subject. To be sure, there is an unfortunate scarcity of mining literature in general, and while the technical journals serve the best purposes to-day in this direction, even therein is noted a marked absence of descriptive matter detailing the general subject of ground breaking.

Abroad, there is but little intercourse between Mining Engineers of the various countries. Indeed, it appears practices in one land are often carried on without the cognizance of those immediately across the line. It is therefore anticipated that this book will be of value abroad as well as in America.

English is as little spoken in mining districts on the Continent as French and German in similar vicinities of the United States. It may be recalled that only a small number of Anglo-Saxons comprehend technical terms even though expressed in the English language. The difficulty of an American traveler whose knowledge of the foreign languages is cursory may therefore be realized. This difficulty is magnified when, as so often obtains, particularly in France, a decided variance exists in the spoken language of different sections of the same country.

L. W. M.

NEW YORK CITY.
January, 1909

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PART I

MINING IN GREAT BRITAIN

THE mineral production of Great Britain has been on the decrease for some years past. Cornwall continues to produce largely, but the methods of mining are antiquated. There the veins are generally steeply thin and inclined.

Some lead and copper is produced in Great Britain. The metal is mined in Devonshire, Warwickshire, and the Isle of Man, but in no instance might the industry be called prodigious. There is but one gold mine in Great Britain, and this is situated in Wales. The iron production of England is third to that of the United States and in coal Great Britain ranks second. Most of the iron emanates from the Northeast and Northwest coast country, where very interesting mining operations are carried on.

Coal is produced throughout Great Britain. In Wales there are some deep shafts and the industry is in a high state of development as regards equipment of the mines. Cardiff is the center of operations. While there is a great deal of coal mined in Scotland, the impression given is that the industry there is not very profitable. Scotland has no metal mines. Wales is strong in the slate-mining industry, though this has fallen off to a great extent, particularly since the slate industry in the United States began to assume large proportions. Ireland has some extensive coal-fields, but, like Scotland, is overlooked in the sway of England's enormous production.

The passenger railroad facilities as a whole are quite as convenient as those of the United States, and while far in advance of those in France, are not equal to accommodations in Germany and Russia, which latter country has the best accommodations in Europe, on its trunk lines.

CHAPTER I. — HEMATITE MINES OF CUMBERLAND

Rich, Hard Iron Ores are Skilfully Mined by the Caving System, which is Essentially a Cumberland Method of Mining

THE county of Cumberland lies on the northwest coast of England, with the counties Dumfries and Roxburgh, in Scotland, to the north, and the Irish sea to the west. In the southwestern part near the sea are the Cambrian mountains. Cumberland produces great quantities of coal and

iron, its iron ore being renowned for its richness and low phosphorus content. The ore is a hard anhydrous peroxide of iron approaching at times the theoretical proportion of metallic iron, although the average is nearer 50 per cent. The kidney form of hematite is very common. Less prevalent is a material called "pencil ore," which brings as much as £100 per ton and is sought for ornamental purposes.

The orebodies of Cumberland appear in every conceivable form. They occur in vein-like formations, in the form of beds and, more often, in irregular masses. The region is much faulted, a majority of the faults running in a northwest-southeast direction. Blue limestone and conglomorate are usually found as a roof over the ore and the floor is commonly slate. Wherever the blue-lime belts are encountered it is well to look for iron, and where the lime horizons are absent, search usually reveals nothing.

It is in the faults that the ore has been given opportunity to deposit. The strongest faults lie in the direction noted, but the general system is crossed by innumerable minor faults. The orebodies are sometimes found in narrow veins, similar to fissure veins in appearance, pinching to nothing in places. In the bed-like deposits, a very consistent thickness sometimes maintains over large areas. The ore brought about 17s. per ton on the basis of 50 per cent. iron.

Methods of Mining

Cumberland is essentially a caving-system country, and no miners are more skilful in conducting the work and the necessary timbering operations than the men of this district. Wherever the caving system is in use the world over, the Cumberland miner stands to the fore. In America he is especially in evidence in the Lake Superior district and in Utah, where the caving system is practised.

Most of the ores in the Lake Superior region are softer than the softest ores which I saw in Cumberland; and only on the Menominee range have I seen ores which compare in hardness with those of Cumberland. In the Lake Superior district the caving system is used mostly on soft ores. The Cumberland ores often appear rather tough, thus differing from the copper ores of Utah and Nevada, where the caving system has been successfully operated.

There is no very marked tendency in the iron-fields of Cumberland to depart from old methods of underground work. For example, there is but one inclined shaft in the district, even though there are several deposits generally admitted to be adapted to this method of operation. The ability of the men to handle fallen ground in caving areas makes up for provincialism in other directions.

The Cornish pump is used very generally in Cumberland; in fact, as

far as I know, there are no steam pumps employed underground in the county and few in the whole of Great Britain. The use of the direct-acting steam pumps underground is not at all favored. The opinion prevails that conveying steam underground and handling the exhaust is no better than a nuisance, and that it is a far less favorable arrangement than the more expensive Cornish pump, and its cumbersome parts.

The air drill, it appears, has not been given a fair trial in this region. The men, although they possess considerable skill in the handling of mechanical devices, prefer to use the hand drill and jack, even in the very hardest ores. It is quite true that in some places the ore is much fractured with many vug-holes and irregularities which interfere with the efficient use of an air drill, but this condition is not so common as to bar the power drill entirely.

CHAPTER II. — PARKSIDE MINE, CUMBERLAND

Pillars of great hight were left to be Eventually Undercut and the Mine Caved. Fallen Ground, after Settlement, was Pierced by Forespiling and the Pillar-ore Recovered. Complete Subsidence of Surface Ensued.

THE Parkside mine is situated at Frizzlington, near Whitehaven, the center of the iron-mining country on the west Cumberland coast. The mine is one of the pioneer hematite producers of the district, but the ore zones are at present pretty well depleted.

The orebody originally worked had the form of a huge wedge, as shown in section in Fig. 1. The orebody dipped at a rate of one to four. The roof was sandstone and limestone, while the floor was underlaid with slate, sometimes replaced by limestone. The sandstone strata above the ore are extremely hard. The condition of the ground above the area from which this orebody was worked is shown in Fig. 2. The mine in this section is impassable, but the general method of working was as follows:

Referring to Fig. 1, a vertical shaft *A* was sunk outside the ore deposit. At 540 ft. a crosscut was driven to the ore and continued as a drift to the hanging wall. From this cross-drift were extended lateral drifts, at 30-ft. intervals, parallel to the strike, and from these laterals, cross-drifts were cut at similar intervals, thus blocking out the ground on this level in 30-ft. squares, by 10 x 10 ft. drifts (*C C*). At 600 ft. in the shaft, a second crosscut *F* was driven, and similarly extended across the orebody. Similarly, from the 600-ft. level, a crosscut was started, and the work of blocking carried out as in the other level.

From the point where the crosscut *F* intersected the orebody, a rise was started on the footwall, which, in these Cumberland deposits, is fairly regular. This rise was extended half-way to the upper level *B*, when a sub-level *N* was started, which would be about 30 ft. higher than the level below. The bords on this level were cut the same size as on the main hoisting levels; in fact, all the work was similar on the sub-level, the only difference being that sub-levels are not directly connected to the shaft.

In blocking out it is endeavored to have the drifts in symmetry, one below the other. The work having advanced sufficiently from the various levels as regards blocking out, rises are started from the upper level to the roof of the orebody, the different levels being connected by rises, to afford air circulation. By successive slicing, the ore is brought down above the drifts. The overburden is kept separate from the ore by means of timber

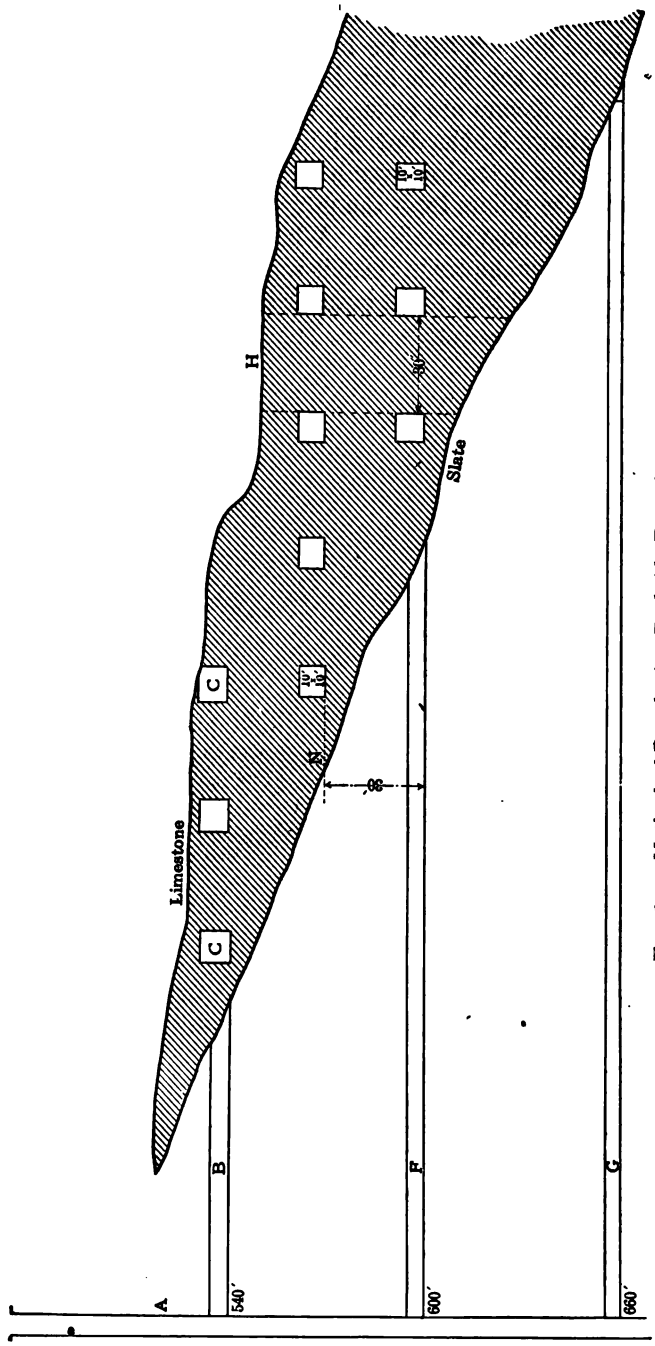

FIG. 1. — Method of Developing Parkside Deposit.

acting as a mat for the waste to rest upon. Simultaneously, at other points, underhand stoping may be in process in drifts, until eventually the interval between the levels has been either raised, or lowered, and finally pillars 30 ft. square are formed, which extend from the hanging to the footwall, as shown by the dotted lines at *H*, Fig. 1.

These operations extended over a long period, and no attempt was made to remove the pillars from the mine until the entire area had been blocked out in the manner described. When it became desirable to remove the pillars and recover the ore in them it was realized that surface derangement would ensue, and that it did ensue is shown in Fig. 2.

FIG. 2. — Surface over Parkside Mine Workings Showing Extensive Subsidence.

The method said to have been used for the removal of pillars suggests great possibilities. Going up the rise, the pillars were undercut, and every effort was made to bring them down, but the rock was not removed at this time. After a shot was fired all loose ground was barred down, the roof about the pillar being constantly tested. Finally the pillar became so weak that it would crush and crumble. The men did not leave the place until it was certain that a cave was imminent. A cave finally occurring, the men waited until the ground settled, barring down loose pieces of rock, by standing on the fallen ground. As this work progressed the cave became more extensive, until finally the entire country subsided.

Settlement having occurred, means were immediately taken to recover the ore in the pillars which had caved. This ground was pierced by means of forespiling, and it is stated that these timbered drifts were driven at comparatively low cost, and were readily maintained in the broken, ground.

As a result of general caving, severe contortion of the surface resulted, which not alone affected the ground immediately above the pillars, but also drove the shafts out of alinement and damaged the surface plant. A common sight in this vicinity is a chimney which, having taken a tilting position due to subsidence, has been straightened up by inserting wedge-shaped bricks on one side in the base, the lower portion of the chimney making a distinct angle with the upper portion.

The areas worked to-day in the Parkside mine are mostly narrow veins, perhaps a few feet thick, in general steeply inclined. Wherever these bodies widen sufficiently, the usual custom is to raise in the ore, block out pillars, and then top-slice these pillars in a manner to be described in more detail later.

CHAPTER III. — CREATOR MOOR MINE, CUMBERLAND

A Flushing System was Devised to Effect Recovery of Great Pillars Attaining 80 ft. in Hight, which stand Vertically between Inclined Walls.

THE mines of Lord Leconfield, at Creator Moor, in Cumberland, were worked as early as the seventeenth century. The hematite orebodies averaged about 75 ft. in thickness, dipping from 20 to 45 deg. Above the ore is a coarse sandstone, called "whirlstone," which in turn is covered by 40 to 50 ft. of clay. The footwall of the orebody is limestone.

As the ground stands to-day, the conditions are similar to those which obtained at Parkside, in Frizzlington, before the pillars were caved. There is simply a succession of pillars, which, in this case, are sometimes 70 ft. square, and in hight approximate the maximum of 80 ft. There is no timber to be seen in this section of the mine. The pillars stand vertical and not normal to the dip. The rooms between the pillars are about 10 ft. wide. It is possible to climb over a great area in the stopes between the pillars. Where the floor undulates to a steep pitch, light chains are fixed above, so that it is quite possible to climb from the lower level of the mine to the top by following the footwall. The method of working was similar to that at Parkside, *i.e.*, by sub-levels and blocking out of the area, involving the final cutting out of the middlings, thus exposing four free sides of the pillar which extended from foot to hanging wall.

A PROBLEM OF ROBBING WITHOUT DISTURBING THE SURFACE

The problem of robbing these pillars presents requirements different from those at Parkside, for at Creator Moor it is imperative that the surface area be maintained. From the standpoint of caving, I venture to say, there would be no hesitancy in attacking the pillars, but this method is prohibited Over certain sections of the mine, where the pillars were no higher than 25 ft., surface restrictions were not important. In these places the pillars were caved and the ore recovered. The method followed was to side-lane the pillar and bring down all roof rock. When the span between the reduced pillar and its neighbor became too great, and the roof treacherous, the latter was shot down, the men standing on the broken rock to further test roof, and work on the upper part of the pillar. When the fall was high, and the broken rock did not present sufficient elevation, ladders were used.

In working with the drill on ladders the miners fixed a plank about

5 ft. long under one of the ladder rungs and passed two loops of light chain under the plank and around the rails of the ladder. This was done in such a manner as would bind the plank at one end, the other end extending out cantilever fashion. The plank served as a platform from which the miners single-jacked at the desired elevation.

In working this ground, if the roof caved before the removal of pillar ore had been completed, the ore was recovered by forespiling through the broken ground (Fig. 3). On approaching the stump of a pillar a

FIG. 3. — Forespiling through Caved Ground at Creator Moor.

second branch drive was sometimes started from another point to expedite the removal of the portion left standing. The aim in the first attack is to cave the pillar, and in forespiling, to draw off the ore in the timbered drift shelter, until the waste rock makes its appearance. In forespiling a part of a pillar may be encountered in comparatively solid condition. In this case mining will be carried on in the ordinary way with a solid face at the head of the drift. When the pillar is a large one, several roads may be driven about it, and through it, until little or no ore of value is left in the area.

The matter-of-fact way in which the miners go about these operations indicates the security which they feel in the work. They are at home in caved or caving ground; it is the ground which hangs and does not submit to control that causes anxiety and calls forth their utmost efforts to induce a fall in the desired way.

Various means of removing the tall pillars standing in the mine without incurring surface subsidence have been considered. A scheme recently outlined involves the filling of the mine with sand flushed in with water,

and to pump out the water. This system to be elucidated in detail later. In my opinion the Creator Moor company has a far more difficult problem than those generally encountered in Germany, and there are certain complications on account of the dip which increase the difficulty.

To convey the sand into the workings, 29-ft. lengths of 5-in. steel pipes, ½ in. metal, were hung in a 6-in. bore hole, and a complete pipeline was in process of erection in the mine. The sand was to be hauled in wagons by a road traction engine, the distance being one mile from the sand-bank. These wagons were of the bottom dump type, and of 4 tons capacity. Criticism of the other surface arrangements for handling sand would hardly be fair at this time because there is no doubt that the management realized the opportunity for improvement and rearrangement looking to economy in handling of sand at the surface.

Gravity Plane, Creator Moor

Fig. 4 shows a mechanical arrangement at the head of a gravity plane. Chains are prevalently used instead of rope thoughout Europe.

Fig. 4 — Form of Devices used Underground in Cumberland.

The ribbon brake, *a*, is operated by the lever, *b*, through the yoke *c*. The form of rail used in these mines is a light angle iron (*e*).

The car in the center of the figure is the type prevalently used in Cumberland. These cars are of about 1000 pounds capacity. The body is of wood, and the wheels are disk-like, with about ½-in. flange, as shown at *f*. These wheels run loose on a 1½-in. axle. The axle-end, *g*, is like a rivet head, and the pin, *h*, holds the entire set intact.

The angle-iron tracks are spiked on to sleepers in the ordinary way. Rails are usually of about 16 lb. weight per yard. Next to each rail is a 2- x 4-in. plank, leaving just sufficient space for the wheel to run on the lower half of the angle iron, with this plank as guard rail.

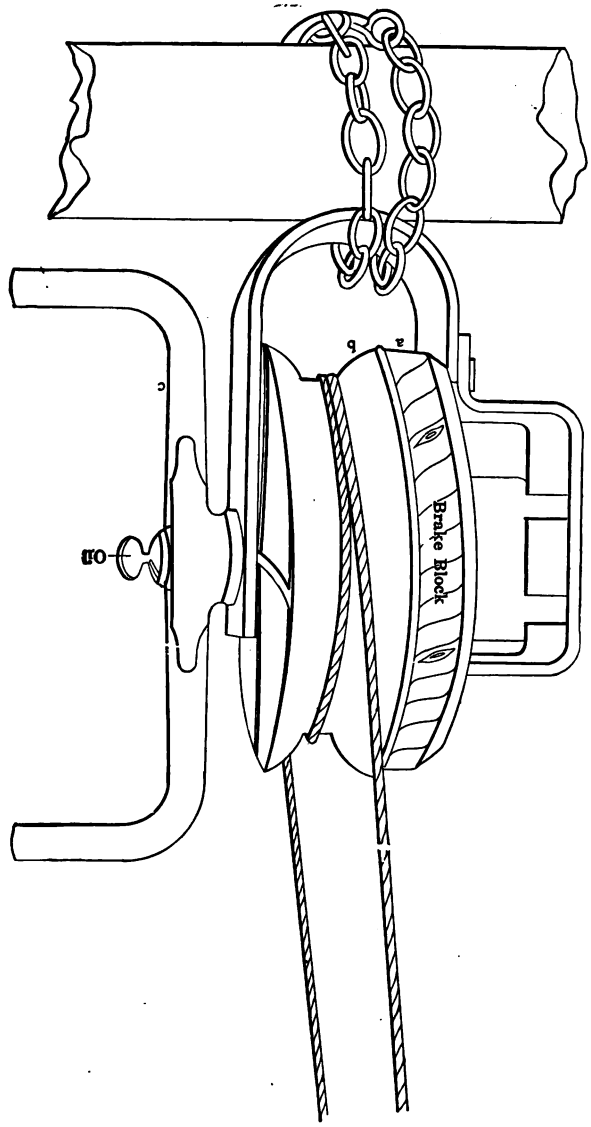

Fig. 5. — Pulley for Lowering Loads in Inclines.

Brake-Pulley Block

A form of lowering device which has met with great favor in England is shown in Fig. 5. This is a patented brake, called a "brake-jig pulley."

It is simple in design, comparatively light, portable, and easy to operate. This device was observed handling approximately a one-ton load down a 30-deg. incline, but the makers claim that a larger device of the same design can be operated for greater loads. The size of device here shown weighs about 50 lb., the pulley being about 18 in. in diameter. *b*, in this figure, is an iron pulley around which the traction cable is wound.

In the lowest depression of this pulley, where the cable comes in contact with it, are occasional small hitches, into which the cable has a tendency to wedge, thus preventing slip. *a* is a wooden block of about the same diameter as the pulley *b*. This is a friction block which is fast to the vertical axle engaged in the center of handle *c*. The handle *c*, on being revolved, raises the block *a*, against the pulley ring *b*, so that when it is desired to arrest the movement of the load, the handle *c* is turned and acts in the same manner as a controller, throwing resistance in or out as desired. The load may be brought to a standstill at any point, and by turning the handle fast can be kept at rest.

The entire device is hung from a chain, wrapped around a post. In another form, the mechanism is fastened to the post by means of a rigid casting instead of by chain.

CHAPTER IV. — ULLCOAT MINE, CUMBERLAND

Hard Hematite Deposit Systematically Developed; a High Extraction of the Inclined Deposit will be Effected by the Caving System.

THE Ullcoat mine is situated at Ullcoat, near Whitehaven. The ore is generally a very hard hematite. A conglomerate roof makes its appearance more frequently here than at the other Cumberland mines visited. The ore is a replacement in limestone, and the floor a Silurian slate: a coarse conglomerate roof is sometimes displaced by limestone or slate. Vug-holes are frequently encountered in the formation; they vary in size, from a few inches, to caves large enough for a man to enter. These vug-holes are often filled with a fine quality of pure plastic clay which is readily extracted and put to good use.

There is the greatest irregularity in the physical condition of the rock, and this, with its hardness, has discouraged the company from giving air drills a fair trial. The drilling is all done with hammer and steel, and it is not surprising to learn that at times the hammermen are doing well when accomplishing a 2-ft. hole in eight hours' work; 8 ft. per shift is near the average. Noble powder containing 85 per cent. nitroglycerin is used in the hard ores, with a No. 6 cap and rubber-covered fuse.

There are three rectangular shafts on the property, this form being rather common in Cumberland. It is the intention to eventually rob the pillars, and the policy now being carried out in development work anticipates this end. It is evident that the company realizes the importance of leaving large pillars, rather than small ones, which latter policy often leads to difficulties in the robbing work.

The two main shafts are 50 and 80 fathoms deep, respectively, the latter having three levels.

The peculiarity of a great many seams in this district is the nature of the out-crop. As the surface is approached, a very soft, loose material is encountered, which has the appearance of thoroughly wetted mortar. This condition led to a serious inrush not long ago, when the work of robbing the upper pillars at Ullcoat was begun. The workings were filled with the soft clayey material, and great difficulty was encountered in reopening the area. A district subject to such inrushes is now bulkheaded so as to confine the incoming material to small areas.

In one seam, which averaged about 6½ ft. in thickness and had a dip of one in three, the ground was thoroughly blocked out in the upper levels

by pillars 30 ft. wide and 40 ft. long. The rises, or bords, between the pillars are 10 to 12 ft. wide. Robbing has been begun in this orebody. In other parts of the mine, work is largely confined to blocking out pillars and, I am told, the large profits of this company are derived wholly from development work, which thus far has been the feature of the operations, particularly in the thick deposits.

Timber Used in Removing Pillars

The method of working after a number of pillars have been blocked out along the lines indicated is briefly as follows: The pillars nearest the outcrop are attacked first. Starting at the top of the rise of the uppermost pillar, a lane is cut about 8 to 9 ft. below the top of the pillar. As the driving of this lane is advanced, timbers are set under the outcrop, the stulls being 8 to 10 in. in diameter. In a case of this kind, where the walls are strong, the cap may have but one post under it, the other end of the cap being hitched into the wall in a recess about 8 in. deep. Similarly, on the floor of this lane, a sill may be set hitched into the wall; where it is impractical to hitch the timber, it is wedged between the walls. Over the sills of this first set, planks or round poles are set, which serve later in keeping the out-cropping material separate from the ore when the overburden is lowered.

The first lane of a pillar having been completed, a second lane is immediately begun about 9 ft. below the top of the sills placed in the first lane. Before doing this, however, the upright post timbers are withdrawn so as to cause the roof over the first lane to drop, the fallen ground being waste material. The second lane is started in the same way as the first, the posts being set under the sills of the first lane, the horizontal pieces which serve as sills for the first lane becoming caps for the second. This, in general, is the principle of the caving system for all widths of vein. In this particular instance the vein was narrow, but in wider veins the principle is practically the same, with exceptions in the details of timbering.

The ore is disposed of by lowering it in small cars. When several pillars are robbed simultaneously, one rise or chamber may be handling the outlet for two adjacent pillars, and when pillars are robbed at different points in the mine, several rises below may be equipped as main inclines down which the ore is conducted to the shaft level. The headings below each pillar may be considered sub-levels connected with the nearest hoisting level by means of the rises between the pillars.

The ore is not necessarily sent to the hoisting level in a straight line, but may be sent down in series of rises or bords which are not in the same plane, but which afford the best available route. The rises which are used for the lowering of ore to the hoisting level are maintained more carefully than the others. Bad roof conditions in certain sections

of the mine determine the choice of haulage location. The re-handling necessary at the foot of various sub-levels, in many cases probably overbalances the cost of maintaining the roadways in a definite straight line.

In the thick irregular deposits, which sometimes become as wide as 100 ft., the work has all been merely blocking out. This has consisted in driving headings and cross-headings 10 x 10 ft., with an intervening middling of 10 ft., *i.e.*, a series of 10 x 10 ft. headings blocking out pillars 30 x 40 ft., then dropping down 20 ft. and repeating this operation. Wherever the deposit shows regularity, these headings are, if possible, kept in the same vertical plane, as shown in the lower right-hand corner of Fig. 8.

Hoisting levels are usually about 60 ft. apart. From the first level raises are driven from convenient points to the top of the orebodies, and from the second level connections are made with the workings on the first in a similar manner. From the top of the raises breaking-out levels are started, and at 30-ft. intervals, sub-levels. The work of blocking out the 30 x 40 ft. pillars may, of course, be carried out at several levels simultaneously, but it is well to do considerable development work first, in order that the form of the orebody may be well determined, permitting an intelligent policy to be outlined in advance.

In the irregular deposits a great variety of conditions are met, and extensions are necessarily made from time to time which, when following stringers, often lead to the discovery of new pockets.

CHAPTER V. — HODBARROW MINE, CUMBERLAND

Great Barriers Hold Back the Sea and the Caving System is in Operation within the Enclosed Area. A Thick, Flat Bed of Hematite is thus Won from under a Pervious Cover.

HODBARROW POINT lies at the extreme southern end of Cumberland, near a town called Millom, which is about a half-hour's ride out of Whitehaven, and borders on a little bay of the Irish Sea. The sea plays a very important part in the mining operations of the Hodbarrow company.

The ore is a hard hematite, averaging about 57 per cent. iron, and lies in great bodies dipping slightly seaward. These bodies are as thick as 100 ft. in parts of the property, while thicknesses of 10 to 20 ft. are common. Above the ore are alternating beds of sand, blue gravel clay, and a harder variety of clay, called "pinnal clay." As the deposit approaches the sea a limestone roof comes in over the ore.

Mining has been going on in this vicinity for many years, but early developments were discouraging, and Lord Lonesdale, the owner of the ground, some time ago granted a lease to the Hodbarrow Mining Company, which is now mining nearly half a million tons annually. Owing to the previous condition of the strata overlying the ore, underground work presents great difficulty, involving not only danger, but also considerable outlay in the endeavor to check the inrushes of sand and water.

During the eighties, a timber wall was built to hold back the sea from the surface area under which the mining operations were to be carried on. This wall was destroyed by the sea, and in 1890 a masonry wall, shown in Fig. 6, was built. Previous to the construction of this wall, the ground had been well prospected. The wall is formed of concrete blocks keyed the one into the other. Puddled clay was used to make the wall impervious to water. The structure stood until a rush of quicksand underground destroyed its foundation, when it began to subside. Following this, a policy of boring under the sea ahead of this wall was inaugurated. Diamond drilling from floats was not without its difficulties, but from the arrangement of holes shown on the company's map, it appears that the work was executed skilfully.

HODBARROW OUTER BARRIER

A large acreage was finally outlined showing a continuation of the ore seaward, and it was decided to build another wall to hold back the

Irish sea. This is the famous Hodbarrow outer barrier, built at a cost of about £500,000. A lighthouse was placed on the wall, in accordance with stipulation of the government when rights to the area were granted.

FIG. 6. — Sea Barriers at Hodbarrow Point.

The length of this new wall is 6870 ft. Its construction covered a period of five years. Its shape is the segment of a circle. The designers were Coode Son & Matthews, who, I understand, also built the Zambesi dam in Egypt. The area enclosed by the wall is about 170 acres, of which, according to the geological maps, at least half shows ore. While it is quite certain that the ore extends farther under the sea, this will probably be the last wall the company will be permitted to build, because of Government restrictions to preserve the river channel.

The form of the wall varies to a certain extent with geological conditions of the bottom. It consists of an outer and inner limestone barrier, formed like truncated pyramids. Within these two pyramids is a wall of puddled clay to make the barrier watertight. The top of this wall is 5 ft. above high water. Where the clay bed underlying the bed was regular, the central puddled clay wall was keyed into the bottom, but where the bed was irregular and formed of coarse sand, 30-ft. sheetings

of steel were driven, the result being a massive steel construction. In front of the outer limestone bank are strewn concrete blocks which weigh from 15 to 25 tons each.

One point has been borne in mind in the design of the structure, the necessity of flexibility; so that in the event of foundation subsidence, the entire structure will sink intact instead of falling by fracture as in the case of the first wall.

Mining Below the Sea Bed

In mining under the enclosed sea area, greater care is required than in work within the shore line. By the terms of lease, pillars of larger dimensions are cut than in the older work. Fig. 7 shows the Hodbarrow Nos. 5 and 6 shafts. In the foreground the effect of mining by the caving system is seen.

All but one of the shafts on the property were sunk in ore, and this one is quite a recent attempt to have a shaft on the property which will outlast the mining operations. The other shafts have been more or less affected by the work of mining, in spite of the fact that large pillars have been left about the pits. Considerable difficulty was encountered in shafts where sand strata were found. A telescopic method of shaft sinking was adopted, starting with a diameter of 19 ft. and tapering down to 11 ft. at 60 fathoms, the difference being due to the thickness of metal in each succeeding length of tubing.

An interesting attempt to introduce the American square-set system was made in one of the large orebodies. This immediately met with considerable favor, following as it did the radically different caving system in use up to that time. The new method worked successfully for a long time in a territory adjoining ground which had been mined out by the old system. However, as the work progressed in the new orebody, the fallen area of the old work was approached, and with insufficient side support for the timber sets, a bad creep resulted in the toppling over of the entire framework. It was then decided to attempt no further introduction of square sets, and the caving system alone has since been in use throughout these mines.

In working the deposits the ground is first systematically laid out in squares by means of drifts usually about 9 ft. square. The policy is to make the drifts as wide as consistent with roof conditions, and 9 ft. has been found to be economical in the greater part of this mine. It is sometimes found that comparatively little timbering is required in the blocking-out work in Cumberland, and the form of timbering shown in Fig. 9 is not uncommon. In robbing, however, timber is freely used.

The method of mining varies to a certain extent at Millom, in accordance with the ore thickness. Where the ore is but 10 or 12 ft. thick,

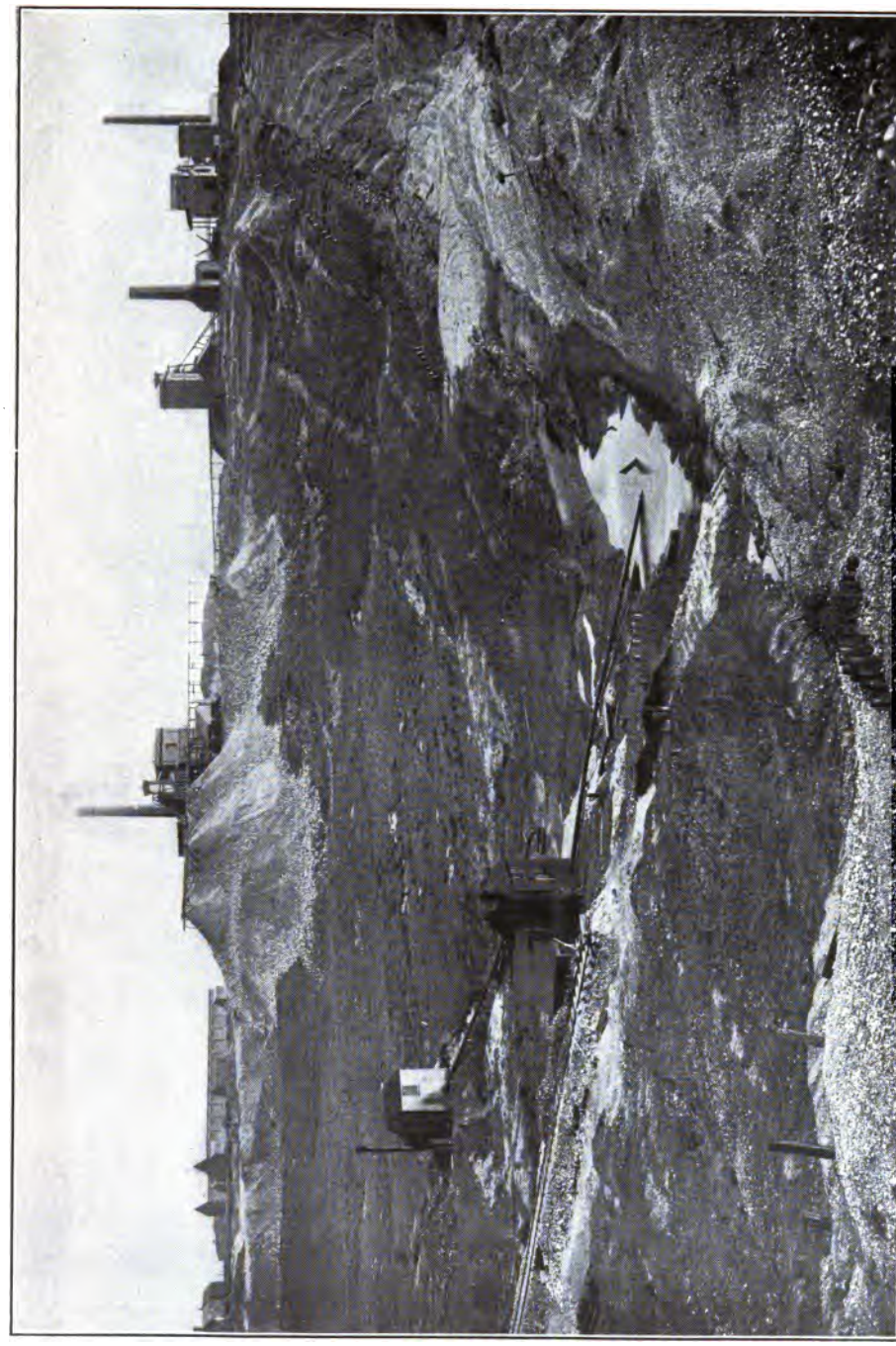

FIG. 7. — Hodbarrow Shafts — Caved Ground in the Foreground.

the system would resemble in a measure the methods used at Cleveland, always keeping in view the eventual withdrawal of pillars. With this thickness, the ore is taken in one lift, and where the overburden is soft, forespiling must be used in all drifts. In the ordinary landward work the pillars are blocked out 30 ft. square, but under the ground reclaimed between the two sea walls, the pillar requirement is 90 ft.

On the left, in Fig. 8, is shown the arrangement of pillars with the interval at which the raises are placed; 6 x 6 in. timber sets are placed one above the other with a 2- to 3-in. space left between each horizontal set. This space is obtained by fixing a block at the corners between the sets. The purpose of the space is to allow room for the insertion of a plank to serve as a staging should it be necessary to perform any work in the raise; or as a support from which tackle can be suspended.

Robbing Pillars and Caving

The ground being well blocked out in advance and the limits of the orebody having been reached, steps are taken for caving the pillars. Where the overburden is hard and blocky, no particular precaution is exercised in laying flooring to keep waste rock distinct from the ore. But where the overburden is soft 2- x 4-in. planks are closely laid on the floor, and the caving roof allowed to rest on same (note Fig. 8 at C.) In the course of the work, should this planking be disarranged, due to crush and movement, more planks will be again utilized for flooring at another level, in order that a clean product may be always delivered to the smelter. Fig. 9 shows a method adopted for mining a seam too thick to be taken in one lift.

The variation in the method of timbering is shown in the upper part of the illustration. On the left, where the roof is strong, the bords are driven wider with less timbering; on the right the bords are carried smaller and more timbering is necessary. It is unlikely that such a variation would be found in so small an area, but the figure is drawn so to illustrate the idea. These drifts block out 30- x 40-ft. pillars of ore in the lower nine feet of the seam. The pillars, finally having been blocked out to the boundary, are later reduced in size.

Seven feet of roof ore is being supported by means of timbering in the drifts. The cap of the set shown on the left would, of course, be reinforced with another post where the pillar is attacked, but such a form of timbering is not uncommon, even in pillar-robbing operations, for when the face of the pillar is attacked it is quite possible that the timbers would be removed anyway, only being kept up to the face to protect the men while they are working there.

It is the aim to cave the pillar and bring down as much of the roof ore overhead as possible, with the minimum use of powder. Assuming

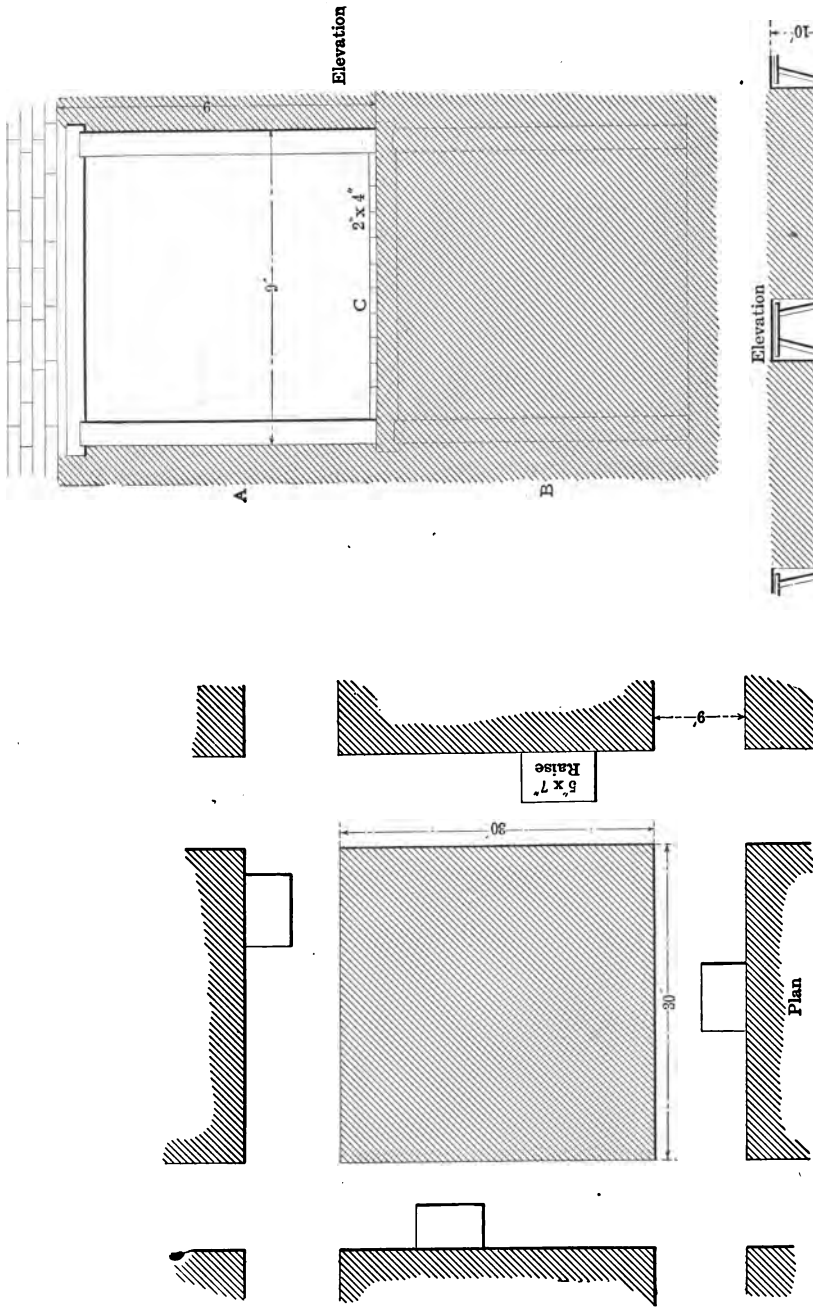

FIG. 8. — A Timber Matte is set on the floor before caving below. Blocking out Pillars and Interval of Raises. A System whereby a Middling is left but finally caved also.

that the 9-ft. pillars (upper part Fig. 9) had been removed, also the timbers of the drift, and a general cave resulted, it is supposed that the broken roof ore occupies 10½ ft., as shown in the lower part of the illustration, and the fall of roof ore has been followed by a local collapse of the roof itself. The drifts shown here are not those shown above (which have been nullified), but are drifts opened up in the broken ore by fore-

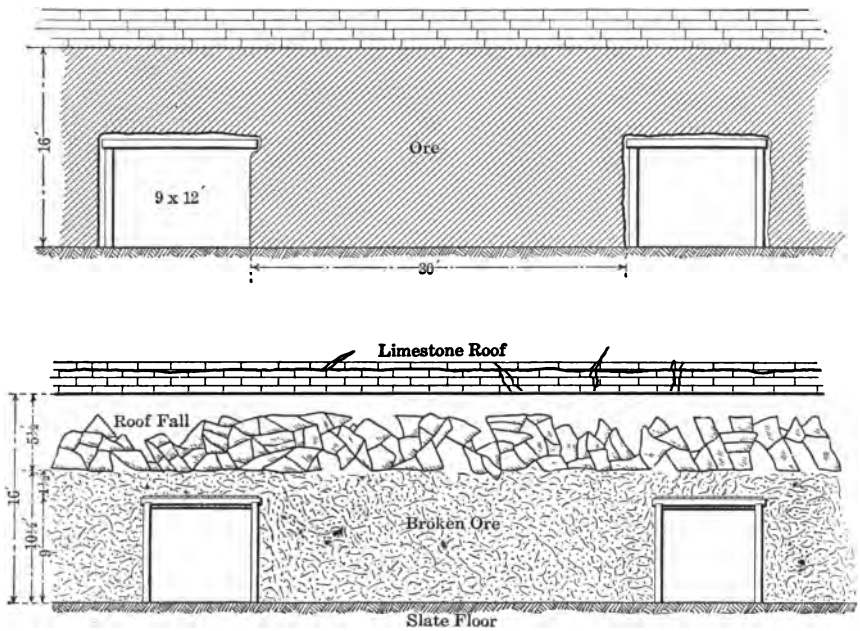

FIG. 9. — Caving a 16′ Flat Bed of Iron Ore — Cumberland.

spiling methods, driven as part and parcel of a second distinct stage of working. These drifts are usually made about 9 x 9 ft., and the ore of the entire broken area is withdrawn through these forespiled drifts and cross-drifts emanating from them. The 1½ ft. of broken ore immediately above the timber drift will be readily won, as the drift timbers are removed on the retreat.

CHAPTER VI. — LONGWALL METHODS OF MINING FLAT SEAMS

Advantages of the System not Appreciated in the United States; Longwall used chiefly in Coal Mining, though it has been Successfully Applied in Metal Mining.

THE most striking feature of mining in the United States, which subject is here introduced for the purpose of comparison, is the infrequent use of the longwall system. This system refers chiefly to coal mining, although instances of its use are not unheard of abroad in metal-mining operations.

By way of explanation, there are in general three systems of mining coal; (1) room-and-pillar; (2) pillar-and-stall; (3) longwall mining. The first is by far the most generally employed in the United States, and is operated for every workable thickness of coal. The pillar-and-stall system is merely a modification of the room-and-pillar method, the room being approached from the haulage-way by a narrow opening called the stall. This opening may be from 7 to 8 ft. wide and 20 ft. long. In comparison to this, in the ordinary room-and-pillar system, the rooms are turned off from the gangway their full width. It is evident that by the pillar-and-stall method the chamber assumes its full width after passing the stall, which blocks out a pillar, left to protect the roof over the haulage-way from which the chamber has been turned off.

By the longwall system is inferred a method of mining whereby complete extraction of the deposit is contemplated on the initial attack. There are two general systems of longwall in use, viz: advancing and retreating, although there are modifications of the system now under discussion. Literature on the subject of longwall mining refers to it in a rather elementary and unsatisfactory manner, and in this country in particular the criticisms are more or less deprecatory.

LOCATION OF LONGWALL OPERATIONS

It appears that the advantages of the longwall system are not realized in the United States. Wherever it is used, it is frequently noted that the operation is under the espionage of men with foreign experience. In England the system is operated in more instances than all the other methods combined, and where in America it is used only under ideal conditions, in England the method is operated under widely diversified conditions of roof, floor, inclination, and thicknesses of seams.

Longwall may be seen in the United States to fair advantage in northern Illinois, where it is used to a greater extent than elsewhere in America. In this district the seams average about 3 ft. in thickness. A few isolated camps in West Virginia and Kentucky are using the system. One determined effort to introduce longwall in West Virginia a few years ago, on a seam somewhat over 5 ft. in thickness, ended in the abandonment of the attempt, mainly because of the inaptitude of the labor for this particular kind of work. There are a few instances of longwall in Iowa and Kansas, though the operations are not extensive. Colorado is a scene of longwall operations at Radiant, where for some time the system has met with moderate success.

In Pennsylvania there are two instances of longwall. The Vintondale Coal Company employs the system in conjunction with underground mechanical conveyers, as does the Cambria Steel Company in one of its mines near Johnstown, Penn. In the far West, there are a few places where longwall is operated, as in the State of Washington. In Pennsylvania, the seam thickness approximated 42 inches, and the work in the seam was carried on to this hight throughout, excepting roadways. In Washington the beds approximate 4 feet.

The Continent has followed the English idea, and in France may be seen modified systems of longwall operated on thick seams. It is not uncommon to see the system used on seams up to a thickness of 10 ft., and the coal taken in one slice, although with complete stowage. Similarly, the system is used on beds as thick as 30 ft.; in such an instance, the work would be carried on in three slices.

Longwall in Metalliferous Mines

The most general use of longwall is in deposits lying approximately horizontal. Aside from the operations of longwall, in coal seams of England, Scotland, France, and Germany, may be noted a number of instances on the Continent where the method is used in metalliferous mines. The Mansfeld Copper Company, for example, have for a long time been longwalling the copper shale in Germany. In South Africa several mines have used the system, though I have not visited this field to verify information to this effect. I understand, however, that on the Black Reef the system has been used, but details on the subject are lacking.

In the United States the occurrence of horizontal deposits is unusual. Sheet ground of southeastern Missouri, where the disseminated lead-ore deposits are quite consistent, presents the most consistently flat formation on the entire continent. The sheet ground of the Joplin district, the Wisconsin fields and certain Arizona copper deposits may be mentioned. Also pyrite mines of California. The possibilities of a modified longwall

system for certain ground, where sheets are extensive and comparatively thin is not beyond reason.

Definition of Longwall

In longwall mining in its true form, it is desired to effect a uniform settlement of the roof, behind a continuous working face. To admit of safety at the breast, this settlement should be effected at a certain distance in the rear. There are certain economic conditions which govern the extent to which ground may be kept open between the face and the gob. The control of roof settlement does not figure alone in the safe keeping of the face, but very strongly in effecting the proper breaking of the material being mined.

On the proper control of the roof depends the success of the system. In coal mining, it is usual to undercut, and the weight of the overlying strata lends its assistance in the breaking down of the coal. If the face is not regular, the weight is not exerted uniformly, and the same may be true if the timbers behind the face are not withdrawn in a regular manner.

Longwall Advancing

In advancing longwall, after sufficient coal has been left about the shaft for its maintenance, the seam may be removed in its entirety to the boundary in all directions. The face may thus take a circular shape, and this is a condition accruing in the Grundy County and Spring Valley fields of Illinois, which former district will be further cited.

It is observed that in advancing longwall, roadways must be maintained in fallen ground, so that the coal may be conducted to the shaft. In true longwall, the structure of these roads is quite devoid of solidity, having been passed through ground thoroughly divested of coal. Ground is maintained by means of walls, built either of rock refuse which may have been stratified with the coal, or else rock is shot down from the roof for wall-building purposes. In thin seams there is usually plenty of packing material close at hand; for example, in a seam of 3-ft. thickness, 2 ft. would be brushed down from the roof in haulage-ways, and the pack-walls would be maintained at approximately 5-ft. hight. An example of work of this nature may be illustrated by describing a mine in the Grundy County field, which may be of interest here to present a general idea of longwall as practised in the United States.

Illinois Mining

The mines are located in a practically flat country, the coal lying parallel to the surface topography. The district is situated about 60 miles west of Chicago, near a town called Coal City. The seam is a bituminous coal averaging 3 ft. in thickness; a typical section of strata over-

lying the coal would be about 7 ft. of surface soil, 16 ft. of sand, 10 ft. of blue lime, 12 ft. of cemented gravel, 22 ft. of sand shale, 30 ft. of shale, and a bottom of fairly hard fire-clay for a floor. The total depth of cover is usually in the neighborhood of 100 ft. Fig. 10 shows the workings of one of the Grundy County mines. The shaft, represented by *x*, is circular. Note the large amount of ground left to support this shaft.

The size of pillar left to support shafts depends so much on local conditions that no definite figures may be given for this feature. It is quite often found in longwall work of this nature that a figure adopted for size of pillar supporting the shaft is of diameter equivalent to the depth of the shaft. At a glance the difference in magnitude between coal- and metal-mining operations is observed in this single feature, and the difficulty of comparison of such a system as this for the working of metalliferous beds, with coal as a predecessor, is apparent.

In Fig. 10, *a a a a*, called "mother-gateways" in England, are driven approximately 280 ft. apart, and practically at right angles to the main haulage road. Room roads *b b b* are spaced approximately 42 ft. apart, center to center. Where the cross-entries *c c c* are turned at 45 deg. from the main roads, the spacing of the room roads is approximately 60 ft., in order to make the 42 ft. of face measured perpendicularly. Entries are maintained 7 x 7 ft. outside of timbers, except the room roads, which are driven just sufficiently high to allow tramming. In some parts of the field soft ground is encountered, and sets of 12 x 12 in. timbers have been observed placed continuously and badly crushed, due to the movement of the ground. The maintenance of roadways in advancing longwall under such a condition as above set forth is, of course, an expensive item, and it is questionable whether the system pays when surrounded by such difficulties; however, ground of such a nature as this would be difficult of maintenance in any system of mining.

Referring to Fig. 11, the roof is propped within 2 or 3 ft. of the face. The use of undercutting machines, or running track parallel to the face, is precluded by the soft nature of the roof. I have seen roofs so strong that it is quite possible to run several sets of track between the face and the gob, should such a course be desirable; props being set, the miner proceeds to undercut the face with a pick to a depth of 16 to 20 in., Fig. 12, *a*. This undercut is 7 to 10 in. high, and is not made in the coal, but below it in the floor. This procedure, however, is not always possible when the loss, due to the undercutting in the coal itself accrues.

The room track, Fig. 12, *b*, is brought up as close as possible to the face without interfering with the work. Coal between room roads, Fig. 10, *b b b b*, has to be carried along the face, where it is loaded into the cars, Fig. 12, *c*. At the face, Fig. 12, *d*, the back is the hight of the seam; viz: 3 ft., but in the entries the back is brushed down to make head

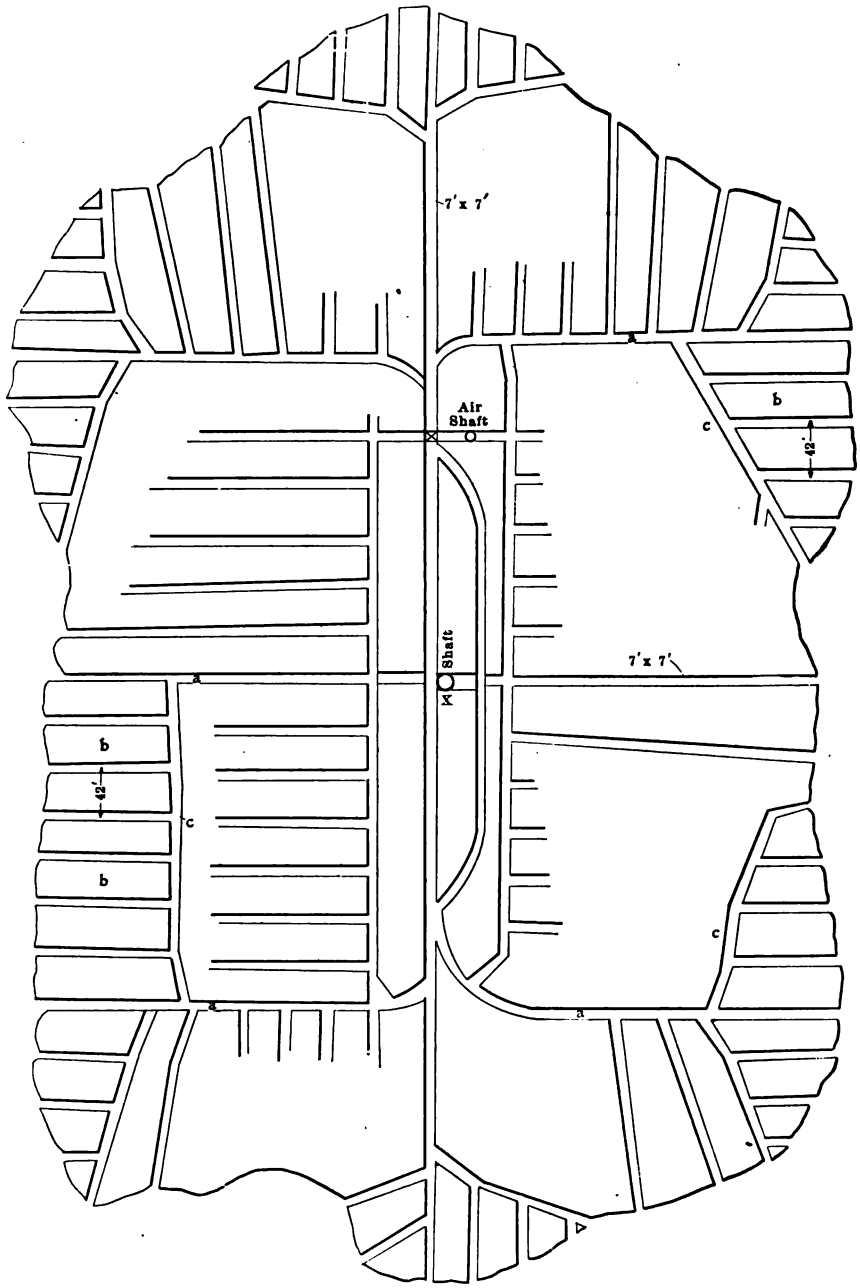

FIG. 10. — Plan of Longwall Workings in a Grundy County Illinois Coal Mine.

room for the tramming. Walls, Fig. 12, *e e e*, and Fig. 13, *e e*, are built up to the roof, which has been brushed down in the roadway to make a hight of 5 ft. However, these walls, as shown in the figure, are only built

FIG. 11. — Lowering of Roof behind Longwall Face.

to a hight equal to the thickness of the seam, since there is no brushing done, excepting in the roadway.

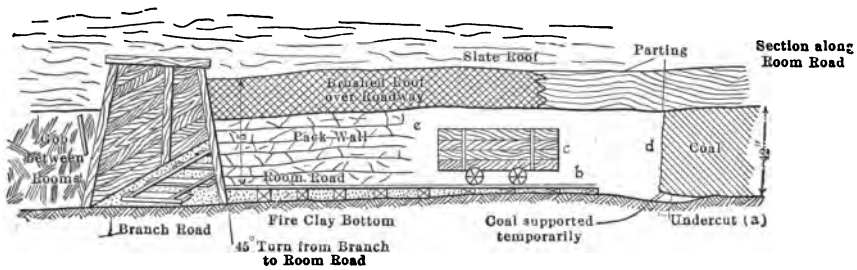

FIG. 12. — Coal Face and Branch Road. Also shows Undercut of Coal at Face.

Between the walls, Fig. 13, *f*, the small material and excess rock are thrown. Where there is an excess of this material, it is hoisted and disposed of on the surface. There is a considerable amount of small material

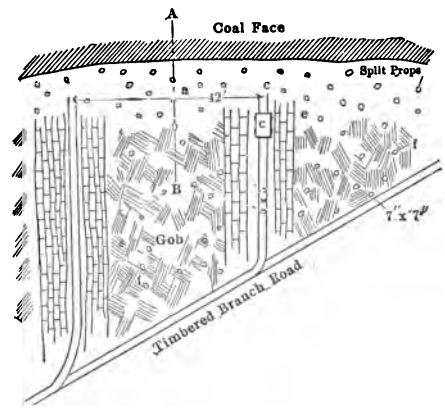

FIG. 13. — Packs and Track Arrangement at Longwall Face.

which is useless for wall building. An examination shows that the amount of waste hoisted is 25 tons for every 100 tons of coal mined.

Cross-roads are usually driven about 200 to 300 ft. apart. The length of room roads, however, is more or less arbitrary, depending on the action of the roof and the facility with which roads can be maintained at length. When the maintenance becomes unduly difficult, a new cross-road is driven and the room roads behind abandoned. Arrangement is made with the contractors who mine the coal, to maintain a certain length of room road and cross-road; 60 ft. of the former and 300 ft. of the latter is a fair requirement, the work of maintaining further extensions devolving on the company. With the formation before cited, it is found that most of the loose settlement occurs during the first two months, this subsidence taking place in a gradual manner. The surface rights are leased with the understanding that subsidence may occur. Pillars are left in the usual manner, to support important buildings on the surface, but elsewhere the entire country lowers acre after acre.

Retreating Longwall

In general, retreating longwall infers the driving of entries to the boundaries and working home to the shaft. The roof is allowed to subside behind the area temporarily supported to maintain the working face. As in any system of longwall, more or less timber is required at the face, depending amongst other things on the nature of roof and floor, which may or may not permit of economic maintenance of track between face and gob. A good condition, in any event, is when there is always sufficient space open between coal and gob to admit of a person walking continuously around the face. It is then assured that the ventilating currents have free sway and that the face is in good condition.

Comparison of Retreating and Advancing Longwall

In comparing the two systems, it may be said for the advancing system, that a quick cash return is available. Whereas, with the retreating system, particularly where seams are thin, and there is considerable rock waste to be mined in the roadways, this feature may involve considerable delay, since the headings are usually driven to the boundaries before mining proper is started. In advancing longwall, the haulage-ways are in ground which is artificially supported, whereas, in retreating work, the roadways are always in the solid, the fallen ground being left to rest behind for all time. This feature of the retreating system is a marked advantage. Following the subsidence of roof, shrinkage of the pack-walls, and the upheaval of the floor, it often becomes necessary to brush down the roof, pull up floor and retimber to maintain the proper hight of roadways in the advancing system.

Since the roads are subject to these conditions, it is evident that constant attention is required, but the seriousness of this matter depends

entirely on the nature of roof and floor, which subject will be discussed later. It would appear that the advancing system, a strike or other cause precluding proper repairs to the roads, may under certain conditions render them impassable, and eventually these passageways would have to be reopened, perhaps at large expense.

It is remarkable to note in some formations how fallen ground will consolidate, and where one would anticipate the necessity of a complete forespiling system of timbering, it is often found quite practicable to support fallen ground with ordinary drift sets much in the same way as the original ground. Where the roads are in packed ground, in the event of a sudden squeeze or other accident, the roads may be rendered useless for escape, wherein lies a disadvantage of the advancing system. It may be said, however, with regard to such squeezes, that they are quite unlikely, since the longwall system involves at the outset a regular subsidence of the roof, anticipating control of both roof and floor. The effect of squeezes in room-and-pillar work is well known to be usually due to the carrying out of the bad policy of leaving pillars too small as compared to room area, which leads to difficulties accruing in the progress of pillar-withdrawal operations. The frequent occurrence of accidents, leading to the rapid destruction of pillars, and the terrific efforts required as a rule to save this action, cites an advantage to the longwall system.

In advancing longwall, the roads probably require more timber in the longrun than in retreating, since they must be kept open in certain locations until the area is depleted to the boundary. The faster longwall can be driven, the better the roof conditions under which the men are working, for as the face advances, new roof is being constantly exposed. This point of speed also figures to an extent as regards timber, for the less time the roof is given to assert its weight on the supports, the more readily will their removal be effected.

Features of Longwall

In general, by using a longwall system, less coal is exposed to the action of the atmosphere. In room-and-pillar work, pillars may stand for years, before being removed, if they are removed at all. Not alone does the action of the air ameliorate the quality of the coal, but dangerous gases in longwall workings are seldom exposed. Retreating longwall, in particular, favors good ventilation, especially at the face. Explosions due to accumulated gases in longwall workings are seldom heard of. In retreating work, this feature is emphasized because there is no reason as in advancing longwall to return through a fallen area if the work was started at the boundary as it should be.

Accidents due to roof falls are less prevalent in longwall work than in any other system of coal mining. This applies particularly to the United

States, for there, as stated previously, only the thinnest seams are worked longwall, and a low roof can always be more readily tested than a high one.

At Carmaux in France, as will be described in this work, the roof attained a 10 ft. hight, over a longwall face, bad conditions were involved since this roof was of a scaling nature and the most thorough timbering was necessary. The coal was friable and even the face was timbered with plank, excepting at those points where the men were picking the coal.

Experience has shown that where a large production is desired from a given area, the same may be accomplished in a shorter interval of time with longwall than by the room-and-pillar system. In general the production per man per shift in longwall is greater, and the cost of mining per ton, under certain conditions where both longwall and room-and-pillar had been operated, favored the former system, to say nothing of the higher extraction of the coal deposit.

American coal engineers in general show disfavor for the longwall system, despite the great success with which it has met in Great Britain, and the following that other nationalities abroad have given the Britishers. The prevailing opinion in the United States is that the system is impracticable where the seam is over 5 ft. in thickness, and it will be then also inferred for an advancing system particularly, that sufficient packing material is stratified with the coal to supply wall-building material. The maintenance of roads in advancing longwall is severely criticised as an item creating a large expense. This is true to a degree, but depends entirely on the nature of roof and floor, so that the inference is not at all general.

The main objection to retreating longwall relates to the tying up of capital for an undue period. However, a combination system of both advancing and retreating longwall may often be operated, and this objection thus mitigated, where speedy monetary returns are urgent.

Assistance of Roof Pressure and Roof Falls

There appears to be considerable diversion in opinion among the authorities as to whether a hard or moderately soft roof is preferable to the longwall system. In this country the latter is decidedly favored, but I venture to state that there are roofs in England, which, though successfully manipulated behind a longwall face, would be considered in America wholly beyond the province of longwall mining. Such a one will be described.

It would be difficult to state whether an infinitely hard roof would be easier of control than an infinitely soft one; the latter is the one most frequently encountered over coal seams.

It is of prime importance that the face be maintained safely and with comparative ease, in order that the quickest progress may be made. A

soft roof will require more attention and more timbering than a hard one. With a hard roof there is often considerable anxiety felt in obtaining the first break in an area, which, however, when once accomplished, permits the roof subsidence behind the face to be readily kept under control. Large areas have been known to hang, which, when they have finally fallen, created more or less windage. Investigation of this subject has proved that this windage is never so strong as to be really dangerous. In the Bengal seams of India, which are thick, and mined from under sandstone roofs by a modified South Staffordshire method, heavy falls of roof have occurred covering large areas. Due notice of the impending fall is always given in the nature of local scaling off of roof rock, and the men have been known to remain in the mines, not far from the active areas, during the period of a fall without sustaining any injury.

Where a roof is so strong that it will not break within a reasonable area, one of the favorable features of longwall is mitigated. The occurrence of the first break in the roof is a sign that the lateral compression in the overlying masses is relieved. Where there is no break there will likely be practically no weight on the face, and consequently little assistance of the roof in the breaking of the coal. It is not to be inferred that powder is unnecessary in longwall mining, for even though assistance of roof pressure is obtained, and the coal be undercut, a certain amount of blasting is usually required to break down the coal at the desired moment.

While the condition of an infinitely strong roof is rarely heard of over coal measures, yet if such a condition was met, and although the assistance of roof pressure to break the coal at the face might be lacking, the feature of a high extraction of the deposit would still be attainable. It may seem an extreme statement to say that no roof is too hard for longwall, but from work observed, it would appear that no roof found over coal is so hard that longwall cannot, for that reason, be operated successfully.

There is no question but that the best way to mine, wherever possible, is to make the first attack underground the last attack, wherever same can be accomplished in an economical manner, this applies to all mining.

A closer study of the longwall system on the part of American engineers would no doubt evolve some interesting innovations in its application. Up to the present time, however, comparatively little thought has been given the subject in the United States, which is strange in a country where speedy and total extraction of deposits is generally looked to, and extreme means usually pressed into service to effect this result.

Roof falls are not always accomplished by the dislocation of the main strata, but more often consist merely in the peeling off of roof strata below the outline of the dome formed in the caving. In longwall with a yielding roof, the ideal action is one of bending of the formation, which

acts on the face cantilever-like. With a strong roof, which hangs, the peeling action above mentioned might occur locally and must be guarded against. If a fall included the main roof strata, no amount of artificial support could counteract it, but the peeling action of the strata below the dome line could be readily supported with props. In Europe it is generally advised that no matter how safe a roof may appear, it should be timbered thoroughly, for the mysterious actions of roofs have been the occasion of more fatalities than any other cause.

Surface Subsidence

Surface subsidence usually follows roof falls underground. The severity of this subsidence depends on the thickness of the seam, the nature of overlying strata and the depth of the seam below the surface. It is well to always anticipate disturbance of the surface, even though the area is completely packed. It has been shown, however, in this regard, that where packing material has been introduced by means of water, such an intimacy can be effected between the particles making up the filling material that surface depression is hardly noticeable, where formerly the introduction of the filling in a dry condition resulted in considerable shrinkage and marked surface disturbance. In America, while the flushing system is used, as will be discussed in a future article in detail, it is rarely introduced in conjunction with the robbing system, but rather as an auxiliary support for the pillars which were not properly arranged in the original layout. No matter in what manner an area is replaced by a packing material there will always be some shrinkage, for the replacement medium cannot be made as solid as the original material occupying this space.

With longwall where surface subsidence ensues, roof lowering is attended with considerably less disturbance on the surface than with pillar work, since the work underground is carried more regularly and the face advances with more accurate alinement and more gradual lowering of the roof. In longwall the roof is watched more carefully, for so much depends on its proper control. This feature should not be minimized in room-and-pillar work. In pillar robbing, however, it is not aimed so much to throw the weight of the roof on the coal, whereas in true longwall this feature is part and parcel of the system. In robbing a pillar, the timbers are usually left standing long enough to admit of as nearly complete removal of the coal as possible. While there is some regard paid to the future of neighboring pillars, if the work is carried on conscientiously, the roof is finally allowed to fall, if it will, in virtue of the removal of the timbers.

In longwall, when the timbers are withdrawn, it is desired that the roof shall come gradually to rest on the pack-walls, whereas in pillar-

robbing work, the roof falls to the floor. True, with a soft floor in longwall the packs are often driven into the floor, but this action is not a sudden one, and the overlying strata when it does subside does so in a gradual manner.

Timbering

Every effort should be made to recover timber and where possible to reuse same. In longwall work, it is most important that all standing props be removed in a systematic manner as the working face advances. With certain roofs, a few standing props may interfere with regular roof subsidence. It is not unusual to see a small prop standing in a thin seam and the roof bending about it, finally reaching the floor. A roof formation of this kind would be considered favorable for the longwall system, in virtue of such a possibility.

Where the roof is hard and the floor comparatively soft, or *vice versa*, a much better condition for ideal longwall obtains than where both are hard. Where a hard roof has taken weight, with a hard floor under it, timber removal may become extremely difficult. The withdrawal of props in such an instance often entails blasting, or otherwise destroying same, to effect its dislocation. With a soft floor, the props might be forced well into it, and their recovery is not such a remote possibility. By tapering the props at one end, the action due to the fracture of timber has been ameliorated. By this tapering the compressive action of the roof, when taking weight, is localized in the tapered area of the prop, which is caused to bur. This burred part may then be sawed off and the prop reused, at a point where a shorter stick is required. Such a form of prop is greatly favored in certain parts of England. It is also found expedient, in setting a straight prop, to pile an amount of small broken stone under it, which when picked away will admit of readily removing the timber even though the roof has taken weight.

CHAPTER VII. — SEATON-DELAVAL COLLIERY, NORTHUMBERLAND

Mining a 6-to 7-ft. Flat Coal Seam by the Longwall System from under an Extremely Hard Sandstone Roof.

THE Seaton-Delaval Coal Company operates four collieries nine miles south of Newcastle-on-Tyne, in Northumberland, England. Northumberland is a county with approximately 750,000 inhabitants, and lies on the extreme northeast coast of England, adjoining Scotland to the northwest, Cumberland to the southwest, and Durham to the south. The largest city, Newcastle-on-Tyne, is the center of a great mining district which is one of the chief coal-exporting ports of Great Britain.

The coal, which is of a semi-bituminous variety, is found in flat seams generally, which vary in thickness from a few inches to 8 ft., and are often overlaid by a hard sandstone formation. Coking is generally practised, though considerable fuel is shipped in the crude state.

The mines embraced in the Seaton-Delaval group are the Foster, Relief, CD and EF, and the Hastings. The total number of people employed at these collieries is 2880, who in six months ending July, 1907, produced 474,129 tons of coal. The company provides living quarters for its employees as far as possible, charging nothing therefor. The houses, of stone, are built on the party-wall plan in long rows, with pleasant gardens and good facilities. When more miners are employed than can be accommodated in the available houses, the men necessarily have to rent houses for themselves. An allowance of 48c. per week is made to help defray the additional expenses of those men who cannot be accommodated by the company. By the payment of 6c. per week, medical attendance is afforded employees.

THE NORTHERN COAL DISTRICT

The Northern coal district presents conditions of roof not found in other parts of England. The roof over the coal seams in this district is uncommonly hard. Outside of the information that certain thick seams in India have particularly strong roofs and are very thick, the roof over certain Northumberland seams is the strongest of which I have record. The Main coal, which lies on a 2- to 3-per cent. dip, averages from 6 to 7 ft. in thickness, with a 6-in. band of dirt 2 ft. above the floor.

The longwall system of mining is here largely and successfully operated.

The two conditions, first, hard roof, and second, comparatively thick seams, makes this district of distinct interest. The roof attains a solidity exceeding any over coal of which I have record, except perhaps the Bengal seams in India. It is decidedly harder than coal-mining experts in America consider within the sphere of the longwall system.

The CD and EF pits are the collieries on which this chapter treats. They produce about 1300 tons of hard steam coal daily. Fig. 14 is a view

FIG. 14. — Views of CD and EF Pits.

of the CD and EF surface plants. Note the peculiar arrangement of headframes. Fig. 15 presents a closer view of one of the hoist houses. The hoisting engine is a vertical steam hoist with chain counterbalance, the chain as noted lowering into a well. The construction of the hoist house might be called reinforced stone, the reinforcement in this case, however, being timber. Note also, from Fig. 14, the close proximity of the pits in each case, the balance being effected between the two shafts over the same frame.

A typical section of strata over a section of the Main coal or Gray seam at the CD and EF pits is strong, hard sandstone, as shown in Figs. 21 and 23. The floor under the seam is often a gray metal for about 2 ft. and then setter clay comes in, which at times is of sufficiently good quality for the manufacture of firebrick. The depth of the Main coal below the surface averages about 360 feet.

Both the longwall and the bord-and-pillar system of mining are in operation, and work which may have been carried on for a time on the bord-and-pillar plan may be changed to longwall, and continued to

the boundary on these lines. Fig. 16 illustrates the condition where the ordinary method of bord-and-pillar has been in operation, the work being

FIG. 15. — Old Hoist House Showing Chain Counterbalance.

changed to the longwall system. In making this change certain precautions must be taken. Pillars must be left to protect the main haulage

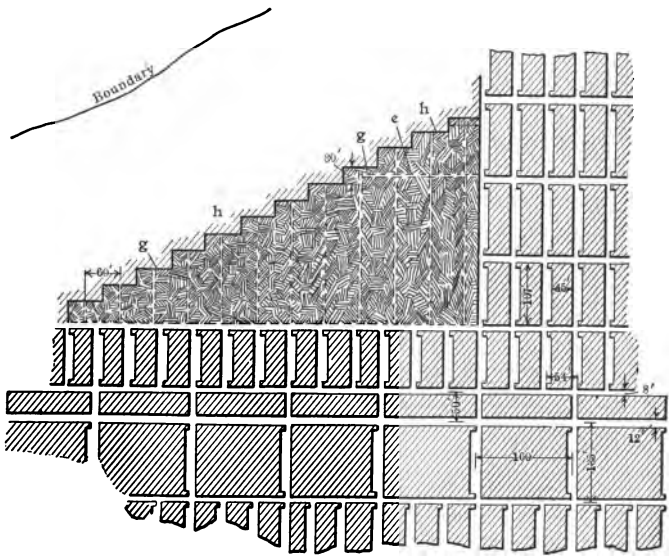

FIG. 16. — Showing Bord-and-Pillar Method Changed to Longwall.

way, should the work emanate in the vicinity of such a roadway, as shown in Fig. 16. In longwalling, it is desirable that the roof should throw its weight on the coal face in certain measure. This is a feature. With a roof of this strong make-up, the benefit so involved would not accrue if merely a small area was set off for longwall operation.

Longwall Gives Larger Tonnage

It has been proved that by longwall a larger tonnage per man can be maintained and that the coal breaks better. It is stated, however, that by longwall the cost per ton of coal is slightly higher than by bord-and-pillar. Nevertheless, when a large tonnage is desired, the longwall system is favored. It has been found at Seaton-Delaval, nearly twice as much coal is cut per man each day by the longwall system.

The evidence here offered certainly controverts the prevailing American disfavor of the longwall system in general; and more important yet, as regards the conditions under which it may be successfully operated.

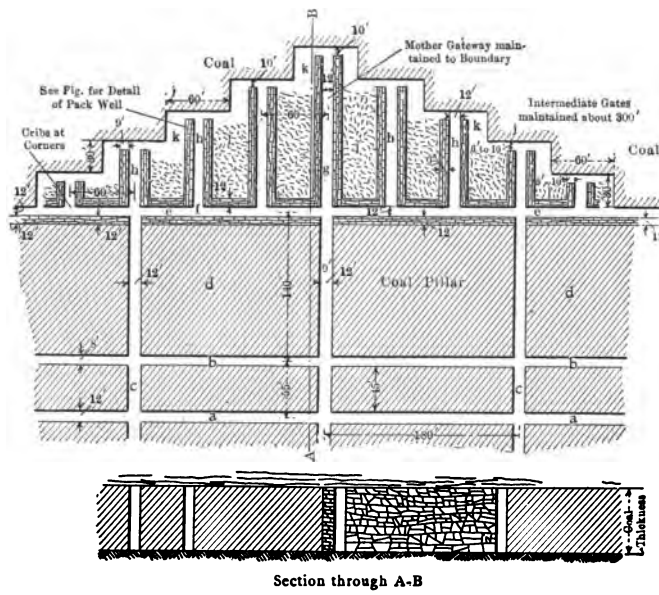

Fig. 17. — Showing Longwall Started from Main Gateway.

In general the plan of mining at Seaton-Delaval by longwall is to drive out from the shaft with a main gateway, and its parallel air course, as at *a* and *b*, Fig. 17, driving cross-headings *c*, *c* at intervals. The barrier pillars, *d*, *d*, *d*, vary in size according to conditions. The road *e*, *e*, is protected by packs of rock, *f*, *f*, *f*, built up against the main road barrier, and from this road, *c*, *c*, start mother-gateways, which are set off at right

angles. These are shown in detail in Fig. 18. The mother-gateways and the intervening subgates are maintained with pack-walls of rock, which material is shot down from the roof in the gateways for the purpose of building these walls.

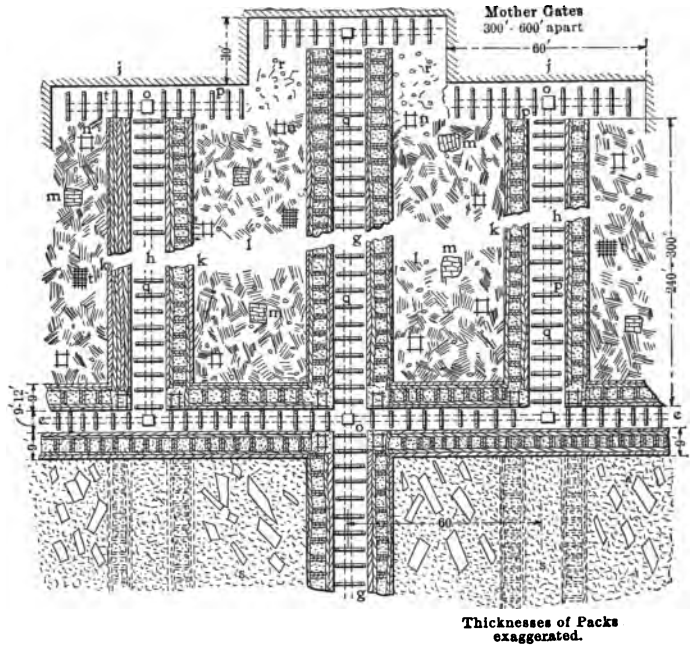

FIG. 18. — Plan of Longwall, Showing Face, Walls and Fallen Area.

The statement may be ventured that, were the seam in Northern Illinois 6 ft. thick instead of 3 ft., longwall mining would never have been carried on, in spite of the favorable conditions existing as regards action, influence, and control, in the light of American ideas. At Seaton-Delaval lies a thick seam of coal, and in spite of the fact that sufficient headroom is available after the seam is removed, and that the roof is very strong — and would be considered impossible in the United States — the longwall system is not alone practised, but looked upon with favor over other systems.

MOTHER-GATEWAYS ARE PROTECTED BY STONE WALLS

Between the mother-gateways which are turned off 300 to 600 ft. apart are the sub-gates. The mother-gateways are maintained until the boundary is reached, and the district divested of coal. Auxiliary gateways are abandoned in the course of the work, and cross-gates *e*, Fig. 18, which are set off from new auxiliary gates, are started. This is in accordance with the prevailing roof conditions.

The main haulageway is driven 12 ft. wide; intervening pillars are 35 to 45 ft. wide, and the return airway 8 to 9 ft. wide. The barrier pillars *d, d,* Fig. 17, are about 140 ft. wide and 180 ft. long. Walls *f, f,* protecting roadway *e, e,* are 12 ft. wide. Mother-gateways are 12 ft. wide, protected on either side by walls 9 ft. wide. On either side of the mother-gateways there may be four or five auxiliary gates *h, h,* Figs. 16, which are kept up usually not more than 300 ft., when cross-roads *e e,* are driven, protected in a similar manner by rock walls.

Fig. 21 shows in detail typical longwall workings at the face. The main gateways *g* are protected on either side by stone walls, which are built close up to the back. The walls are not built solid, but have a 1½-ft. shell, small stuff being thrown in the center. Details of wall are shown in Fig. 19. It is noted that the roof is brought down only in the gateway itself, Fig. 22, and only to such an extent as to afford sufficient rock material of proper size to build the walls.

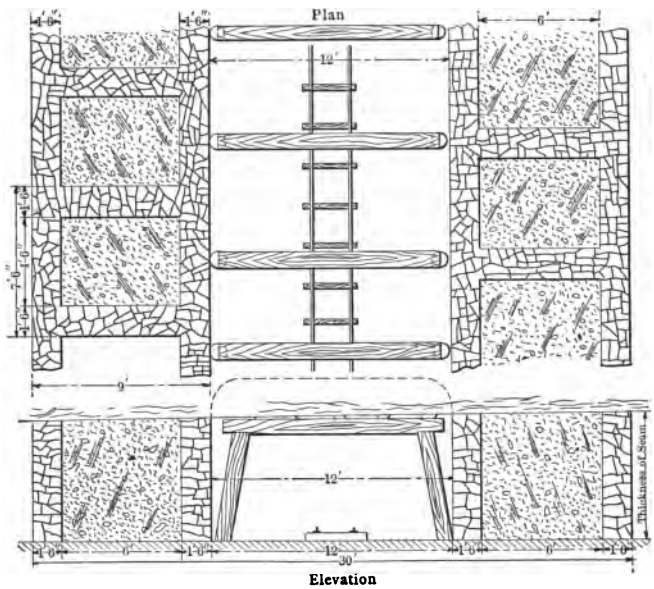

FIG. 19. — Detail of Shell Walls built either side of Gateways.

THE COAL FACE IS STEPPED TO PREVENT ROOF BREAKING AT FACE

Note in Fig. 18 how the coal face is stepped, *j, j, j,* each stall being about 60 ft. wide, and stepped 30 to 45 ft. deep. This layout, as previously described, counteracts the tendency of the roof to break at the face.

The rock walls are kept up within about 10 ft. of the face. At intervals, as shown in Fig. 18, stone cribs *m, m,* about 6 ft. square, are built,

and these are supplemented by timber cribs *t*, *t*, sometimes filled with stone. Fig. 20 shows a timber crib built and wedged up to the roof at a point where two roads intersect. The thickness of seam at this point, it is seen, approximates 8 ft. and is exceptional, rather than the rule. It is not to be inferred that these walls keep the roof up permanently; there is no intention that they should.

FIG. 20. — Shows Timber Crib Wedged to Roof at Intersection of Two Roads.

In spite of the hard roof conditions here, a regular subsidence is effected. Just what the result would be if the floor were of the same hard nature as the roof, is hard to state. I am inclined to believe, however, that the walls would be crushed, for nothing can stop the roof if it starts to come down. As it is now, the walls are crushed to a certain extent, but the main subsidence is due to the walls being forced into the floor, and the heaving up of the floor due to roof pressure.

As in the softer formations where longwall is used, the mother-gateways have to be gone over periodically, and settlement occurs to such an extent that headroom has often to be recut two, three, or more times, during the life of a roadway.

WORK IS DIVIDED INTO THREE SHIFTS

The mining work is divided into three 8-hour shifts, the first two shifts being hewers, and the third stonemen. During this last shift nothing but stone work is carried on, the men so engaged being called "stonemen" and "shiftmen," the former being wall builders and the latter rock drillers.

The foreman over this work is called the master shifter. Rock work is always done by the same crew, and during the same hours, the stonemen or shifters always working at night. Shifters are in the mine from 4 P.M.

FIG. 21. — Showing Strong Sandstone Roof over the Gray Seam.

until 12.30 A.M., and have some roof rock broken down ready for the stonemen, who come in at 6 P.M., and remain until 2.30 A.M.

Figs. 21 and 22 show a mother-gate within about 15 ft. of the face. In

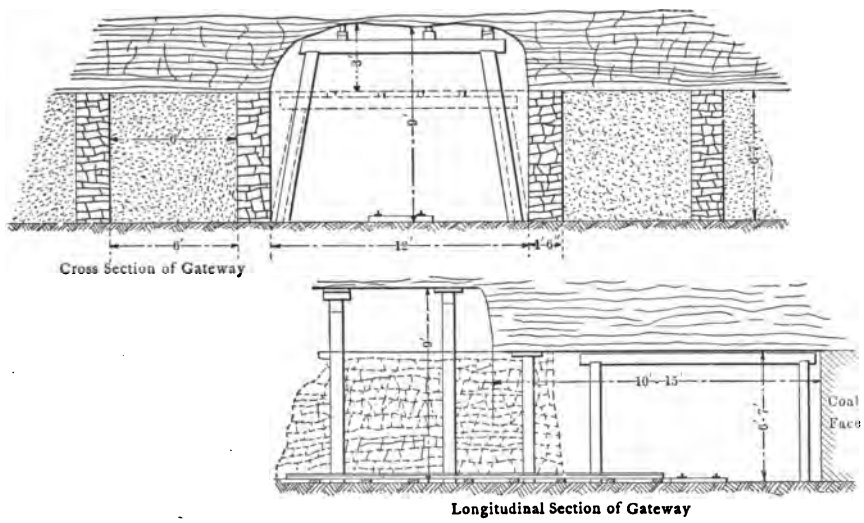

FIG. 22. — Showing Detail of Walls and Roadway. Also Roof Work Following Coal Face Advance.

Fig. 21, the roof rock is intact up to the point where the man points his finger. In Fig. 23 the timber has been removed, and two shots have been fired, having produced the fall illustrated. On the extreme left is shown the wall which protects this side of the gateway. In bringing down the roof, certain timbers are removed and others left. It is surprising to see how the form of break desired is readily controlled by the arrangement of these sticks. The longwall face is seen in the rear of both illustrations, at the head of the mother-gateway; also the 6-in. dirt band about 2 ft. above the floor in Fig. 21. The stratification shown in the rock, Fig. 23, are not necessarily general; at times this sandstone formation is most uniform.

FIG. 23. — Showing how Roof Rock is blown down in Roadways for Wall Building Purposes.

Two men who get from $1.20 to $1.44 per day, work down as much rock as can be packed in a single shift by the stonemen, who in turn get $1.08. The hewers were getting $1.24 plus 38 per cent. at the time of my visit. It may be mentioned here that for work in England there is a base price, settled on by a conciliation board, which includes representatives of both operators and workmen. In Northumberland, the board meets every three months and graduates the percentage to be applied to the base price according to the prosperity of the trade.

The stone builders work four men in a gang, and aim to build 6 lin. ft. of wall on each side of the road per shift. It is seen in Fig. 19 that cross-walls are built at 4½-ft. intervals; these are also 1½-ft. thick. In Fig. 19, note that 3 to 5 ft. of roof is brought down over the 6-ft. seam, so that the gate area is 9 to 11 ft. high. This is also shown in Figs. 21 and 22,

although at that point the seam is only about 5½ ft. thick. In a 6-ft. seam, each man handles 162 cu. ft. of wall-building material in eight hours. Each 6-ft. advance on both sides of the road means 36 lin. ft. of rock wall built, and 324 cu. ft. of gob. This is 81 cu. ft. of each class of material handled by each man.

Building the Walls

The rock which makes up these walls must not be too large. Usually it is broken up so small that two men can handle any piece without extreme exertion. The limit of 200 lb. might be placed, though perhaps for the lower tiers of rock heavier material can be handled with impunity. The wall building, it is seen, is entirely dry work. Placing short lengths of round timbers in the walls horizontally, as is practised at the Baltic copper mine in Michigan, in the built-up stone drifts, has been tried with good effect at Seaton-Delaval. Their presence tends to bind the walls.

Hand-boring machines are used for drilling the holes. Ordinary augur drills are rigged up, to be set to a 9- to 10-ft. back, the hight being adjusted by telescopic standard. In hard rock, the augur is turned by two men, and ¾-in. diameter holes are drilled 4 to 5 ft. in length, slightly inclined upward. The speed of this drilling is variable. A hole 4 to 5 ft. in length may be drilled in from one to five hours, according to the texture of the rock. In just such a place as is shown in Fig. 21, the telescopic standard will be set up and the hole drilled at a point a little above where the man's finger points. Two such holes may be placed to produce the effect shown in Fig. 23. Four to seven sticks, equaling 20 oz. of ammenol powder, are used per charge in dry work, with 5 ft. of black Bickford fuse No. 7 cap. Where the ground is wet, gelatinite made by the Alfred Nobel company is used. Sticks are 4 in. long by 1¼ in. diameter. This explosive is stronger, but produces considerably more smoke than ammenol.

The roof is necessarily timbered in a thorough manner, as is required by law, though the absolute necessity of the timber is not always urgent. Maximum bracing between spaces and props is stipulated for all conditions of roof, and the law allows little variance. While a certain amount of timber is always used, considerably more is set up than is apparently required. The amount, of course, is dependent on the nature of the floor, quite as much as it is on the nature of the roof. Where the roof acts too quickly, the coal may be shattered more than is desired, the aim being to produce as much large coal and as little slack as possible. The amount of timber used in the mine is also dependent, to a great extent, on the prevailing atmosphere in the workings.

Robbing Pillars and Letting Down Roof

Pillar-robbing operations, called "broken work," are always started from the boundary, and progress on the retreat, but where excessive evolution of gas is not likely to follow the roof falls, the work of robbing may be carried on in isolated districts, pillars being left for the support of haulage-ways, etc. Fig. 24 shows a single pillar in various stages when under attack. Starting at 2-a, a place is cut 9 ft. wide; *b*, called a "stook," 9 ft. square, is left as a pillar of protection. A cut-out, *a*, is run out the length of the pillar, maintained 9 ft. wide. As this work progresses, timbers are set continually, and withdrawn. The timber sets, consisting of two posts and a cap, are augmented by cribs, as seen in 3, 4, and 5, of Fig. 24. These cribs are set at intervals as required, perhaps 12 ft.

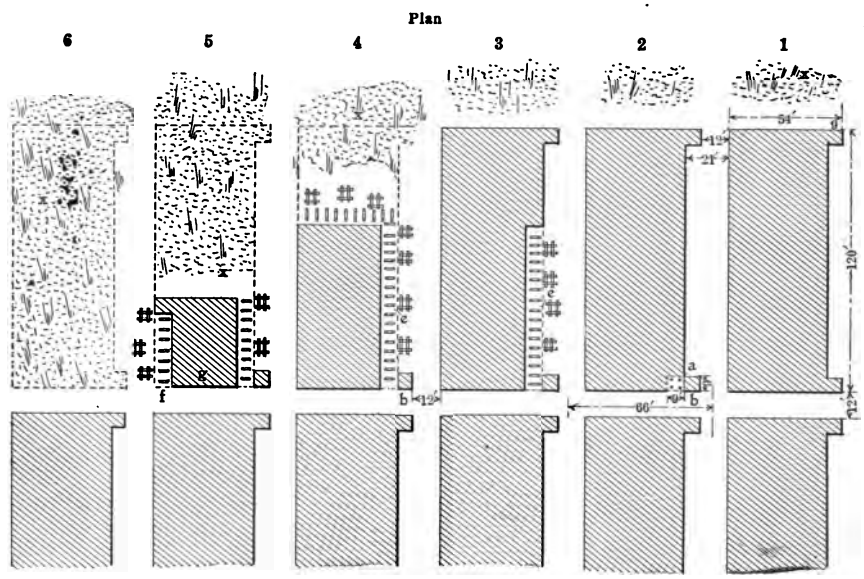

Fig. 24. — A Single Pillar, Showing Stages of Attack.

apart, and are approximately 6 ft. square; they are often made of old, discarded timbers. On reaching the goaf, a headway lift 9 ft. wide is cut across the short end of the pillar, next the goaf end, and successively other 9 ft. slices, until finally the pillar is all removed within about 15 ft. of the near end. Up to this time the timber has been set and removed, following the judgment of the deputy overman. Only a small portion of the coal now remains in the pillar, and its complete removal is not always certain. The last part of the work is carried on with particular speed, until finally the coal stock, *b*, remains to be drawn.

The letting down of the roof does not always follow as desired. This

work is directed by deputy foremen, whose special duties are to oversee the removal of timbers. They are held accountable for the safety of the working places.

It is not unusual for the roof to hang over an area of two or three pillars, and then to fall suddenly, although never without warning. This condition of sudden fall is, of course, precarious. When the roof does come, more or less crushing of coal, with ensuing loss, occurs in the adjacent standing pillars.

Surface Subsidence

Subsidence, it has been observed, is dependent on thickness of seam, nature of overlying formation, depth of seam from the surface, and other conditions, such as whether other seams have been worked above or below. At Seaton-Delaval, experience as regards subsidence of the surface has been variable. In one place, a 5-ft. seam of coal 672 ft. from the surface, with 300 ft. of strong stratified post and blue metal followed by a hard formation to the surface, was mined for an area of about 1500 acres. The floor in this case was hard; there was no surface effect noticed. This was in an area called the "Low Main" seam. Another instance was cited of a seam 5 ft. 8 in. in thickness under a 360- ft. cover, consisting of 12 ft. of strong post over the seam, followed by 20 ft. of gray post and other soft strata, which involved complete subsidence; the floor in this case was considerably softer than in the former instance. It appears that where longwall has been operated, the subsidence was not so severe, the cover being allowed to fall in a more gradual manner.

CHAPTER VIII. — CHOPWELL COLLIERY, NORTHUMBERLAND

Longwalling a 2-ft. Coal Seam without Pulling Roof for Additional Headroom

THE Chopwell colliery is one of three operated by the Consett Iron Company, in Northumberland, England. It is situated at Chopwell, near Rowlands Gill, which place is about 12 miles southwest of Newcastle-on-Tyne. Coal here mined is very good for coke making, and the company has an extensive battery in operation which cokes the greater part of the mine output.

There are several seams mined at Chopwell; the ones most worked at present are known as the Brownwell and the Townley seams. The Brownwell is 2 ft. 5 in. thick and lies 65 fathoms under an overburden which has comparatively flat surface topography. Above the coal is generally found 3½ ft. of blue metal which, though quite hard, is not as consistent a rock as the post, often lying directly over the seam. Where the blue metal is found, instead of the post, the regular sandstone usually follows the blue metal to a thickness of 6 ft., and above this occurs about 36 ft. of alternate bands of blue metal and post. Then comes a succession of four coal seams which vary in frequency, the interval averaging 20 ft. The thinnest of these is 1 ft. 10 in., and the thickest 3 ft.; they all have either the blue stone or post roof. Ordinarily the method of working would be to attack the upper seam first, but these seams are so thin and the roofs of such a nature that any of the seams may be worked without regard to the others. Subsidence is felt to a degree in the upper seams, as a result of having worked the lower ones previously at certain points. This effect, however, has not been felt to such an extent as to make it significant.

The haulage road, within which a system of main and tail rope haulage is operated, is driven 9 ft. wide and maintained at a hight of 5 to 6 ft. In this, the Townley seam, Fig. 25, supporting pillars on either side of the haulage road, are left 72 ft. square. A system of mining has been advanced along the lines shown by Figs. 25 and 26. Of late years the underground conveyer has met with much favor in Northumberland, particularly in this district.

METHOD OF MINING

In the ordinary method of longwall mining the stentons, *a*, *a*, Fig. 25, are driven 15 to 20 ft. wide (*a*, *a*, Figs. 25, 26 and 27), and these are driven

up until they reach the next drive, where they stop, and a piece of coal 18 ft. wide is brought back (*b*, Fig. 27), thus leaving the width of stenton, plus this cut, within which is packed the stone broken in making the 5 to 6 ft. hight in roadway. In Fig. 26, is shown a style of longwall

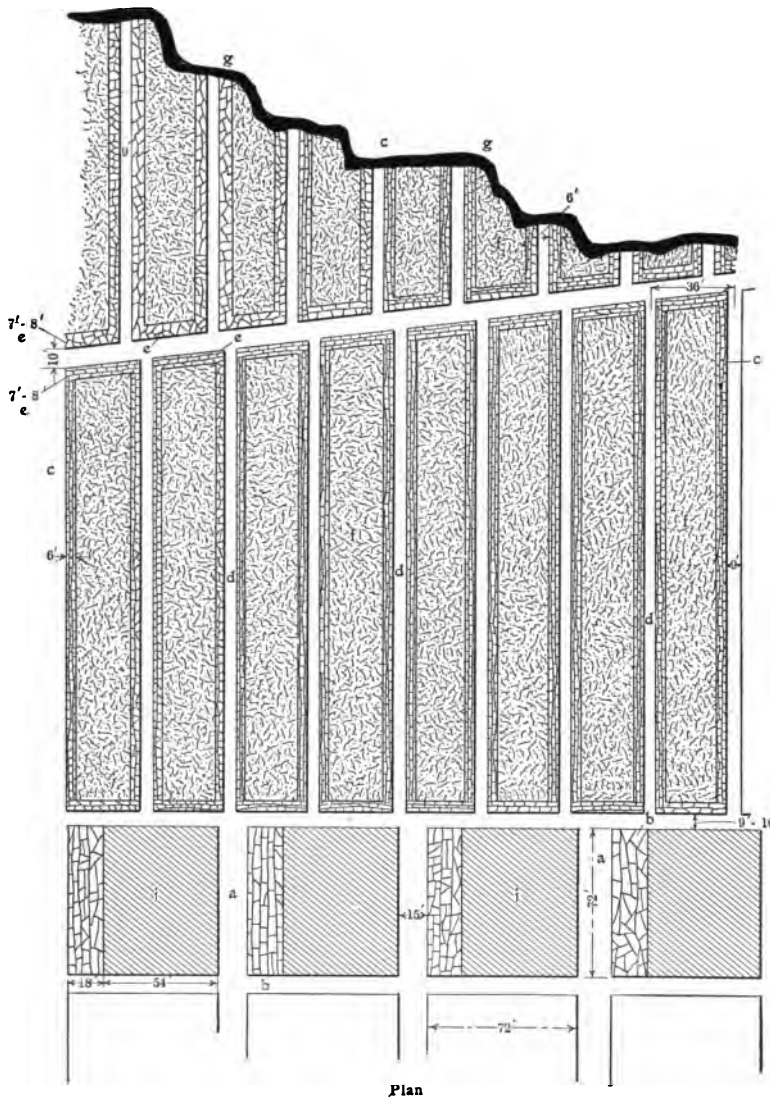

FIG. 25. — Old Method of Longwall.

operated. The old style, Fig. 25, is still used. The gateways are driven 36 ft. wide, *d*, *d*, *d*, with the tub-road in the middle. On either side of this road, pack-walls, *c*, *c*, *c*, are built 6 ft. wide and to a hight of 4 ft.

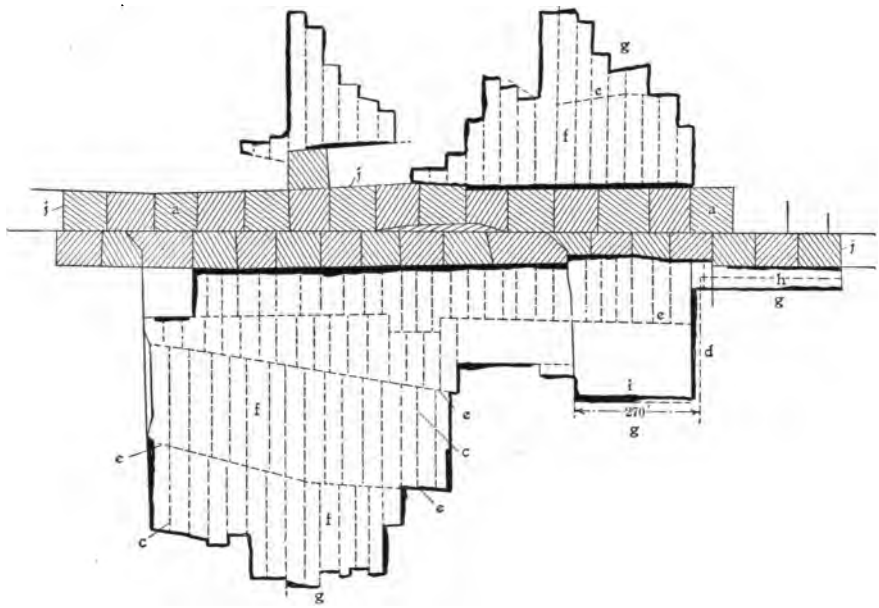

FIG. 26. — Plan of a District Underground.

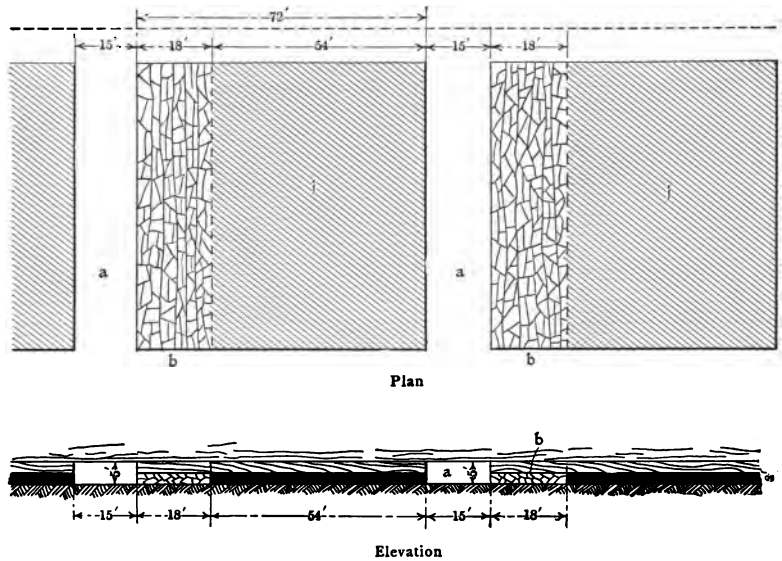

FIG. 27. — Roof Rock Broken in Roadway is Packed in Pillar Area.

3 in. The seam being 2 ft. thick, sufficient stone is shot down to make up the other 2 ft. 3 in. This stone is shot down much in the same way as at the Seaton-Delaval, hand-power rotary drills and ammenol powder being used. It is claimed that in 8 hours nine lineal feet of roadway are cut, timbered and the walls built, this work requiring two men who get 3 s. 9 p. plus the county percentage. This, at the time of my visit, made their wages 6 s. 4 p. 3 f.

Gateways are discontinued at approximately 200 ft., and a cross-drive, *e*, *e*, *e*, *e*, Fig. 25, is run. In these headings the packs are made 8 ft. wide, whereas in the other headings they are made 6 ft. The 200 ft. is found to be an economical length for gateways; after that point the expense of driving and maintaining a cross-gate is less than the maintenance of several old gateways. This process is continued until the property line is reached, no coal being left in the mine, except that left in pillars for haulage road protection.

In all advancing longwall work there is much expense involved in the maintenance of communication from the face to the main road. Since this road runs through ground lacking solidity the support is entirely artificial. The distance between cross-headings is a variable factor, depending entirely on the condition of roof and floor. Where this condition is unfavorable one of the great objections to advancing longwall work is emphasized.

Underground Mechanical Conveyers

The coal is moved from the working face to the main haulage road by means of conveyers, consisting of sheet troughs in 6-ft. lengths supported on short legs. A chain of rectangular detachable links is caused to drag within the system of troughs. The chain is given its motion by an 8 h. p. motor (Fig. 28). The controller may also be seen in the foreground to the right. This is the discharge end of the conveyer.

As seen in Fig. 29, mother-gateways, *c*, are driven at right angles from the main road approximately at a 540-ft. interval to a width of 10 ft., each mother-gate being in control of 270 ft. on each side. Conveyers from each block run in opposite direction toward the mother-gateway, and discharge their load into tubs, which are hauled up the mother-gateway by rope traction. Either side of the mother-gateway at 270 ft. distance is a back gate, *e*, *e*, Fig. 29, driven 6 ft. wide and 4 ft. high, which affords the return air course. As before noted, each mother-gateway is the road for two coal faces, but the conveyers from both faces do not discharge into tubs at the same point in the mother-gateway (*d*, Fig. 29). The purpose of this is to allow ample room for switching and spotting cars.

In mining, the mother-gates are always kept in advance of the coal face to allow tail room for the cars.

FIG. 28. — Conveyer Discharging into Car in Haulage Road.

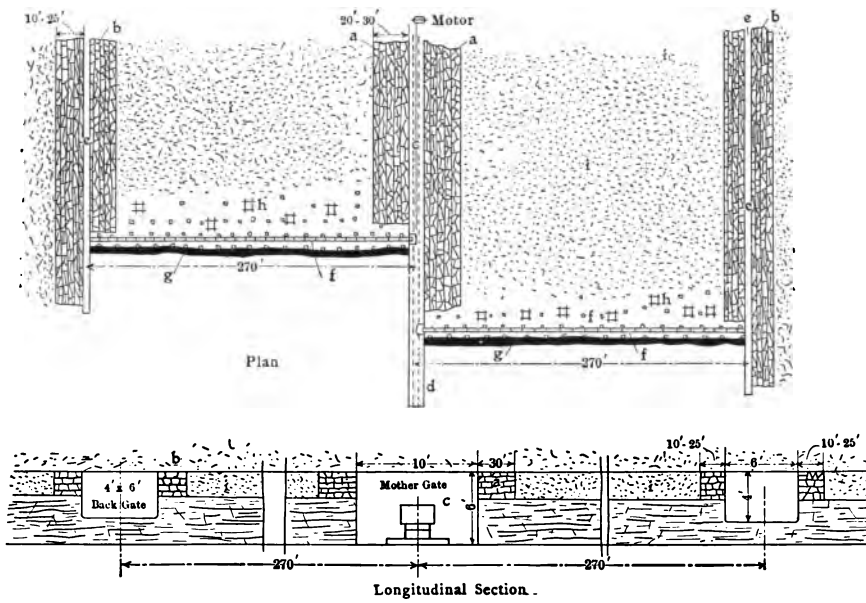

FIG. 29. — Longwall with Conveyers at a 2-ft. Face.

Operations at a 2-Foot Face

The operations at the face are the same as at Vintondale, Pennsylvania, except that all work is on the advance, and that no powder is used in mining coal. Fig. 30 shows a man shoveling coal from the face into the trough of a conveyer. The seam at this point is 1 ft. 11 in., and the manner of working is the same all the way through. This illustrates the apparently contorted position in which the men are required to work. About every 12 ft. a timber crib is placed.

Fig. 30. — Shoveling into Conveyer at a 2-ft. Face.

The dash with which the men work is surprising, as well as the speed with which the moving up of the conveyer is accomplished. Note the depth below the seam to which the floor was taken. Were this not a conveyer system with the requirement of difference in elevation from the discharge end of the conveyer to the car, it would have been likely that the hight in the gateway would have been made rather by brushing down the roof than pulling up the floor. This is not intended to be a broad statement, inasmuch as, if there had been a soft floor as compared to roof, the method of taking up the floor would unquestionably be most desirable.

Each conveyer then is 90 yards long and the output of each approximates 120 tons in 2 shifts, broken and shoveled by 10 men per shift. During the night shift five men remove timbers, set up conveyers, and replace timber where necessary. In setting the conveyer, they start at one end and move it up without separating the different sections.

A hanging roof is occasionally met with here, but as a rule there is no difficulty in getting the top to come down from day to day. It was my good fortune to see a roof in the act of subsiding. The props were being removed in one place, and when this work was completed the roof gradually came down without breaking up. The action was purely bending for a time, until a break occurred before the roof had reached the floor.

A huge Seamans-Halske electric percussive drill was being tried at the colliery, to drill roof rock in the roadways. The machine worked fairly well, though not manned by experienced men. It was, however, entirely too heavy and bulky to be considered an efficient machine for anything but possibly level work. A 6-ft. column on which the drill and motor were hung approximated in weight an ordinary 3-in. Ingersoll drill. The reciprocative return motion is obtained by means of a heavy spring. The motor was on the drill body and power was transmitted in the ordinary way from lead wires, connected up in the haulage-way.

CHAPTER IX — KIMBLESWORTH COLLIERY, NORTHUMBERLAND

Five Seams are Worked Varying from 2½ to 5 ft. in Thickness. The Roof is often Extremely Hard and it is then Difficult to Effect the Initial Break.

THIS colliery is situated at Plawsworth, Northumberland County, England. Five seams are being worked, which vary from 2½ to 5 ft. in thickness. Both bord-and-pillar and longwall mining is operated. Bord-and-pillar is usually used where packing material for longwall work is not at hand.

It is at this colliery that the Blackett underground conveyer was first used. This is the type in operation at Chopwell and in other mines in England, as well as at Vintondale, Penn.

METHOD OF MINING

Overlying the 4-ft. seam is 500 ft. of cover, 30 ft. of which, directly over the coal, is a hard sandstone post. The hand-power rotary drill will not answer in this material; in driving the original haulage-ways percussive air drills were used. Under the hard roof before mentioned, pillars are cut 60 by 90 ft., taken off a heading 10 ft. wide, with bords of 15 ft. width. Pillars are robbed on the retreat from the boundary, keeping the line of retreat at approximately 45 deg., as shown in Fig. 31. In this way the weight of the roof is kept over the coal, whereas if the line of retreat were parallel to the roadways there would be a greater unsupported area at the time when the line of break is passing this roadway. A method of attacking pillars is shown in the plate, where same are removed by cutting 15-ft. lanes parallel to the long side of the pillars; thus each pillar receives four cuts on each half. In this colliery the tapered prop is largely used and much favored. The props are purchased with the ends tapered. The timber comes from Scotland.

The first fall of roof once accomplished, all is well and the work is carried on in a safe and systematic manner. Some difficulty, however, is often encountered in producing this first fall. First of all a center lane is cut, which may be started from both sides of the pillars simultaneously, or from one end. As soon as this lane has advanced far enough, one of the side lanes may be started in each direction. Where roof conditions are very good, the lane may be started in each direction from the center lane, and at the same time from the headings toward the center of the

pillar, so that in this way speed is made. Pillar 1, and half of 3 and 4, are supposed to have been entirely removed, and the roof only supported with timber sufficiently to accommodate workmen in the center lane in pillars 3 and 4. In pillars 7 and 12 the center lane is in course of driving. In pillar 7, lane *c* has been started from the heading above, and in

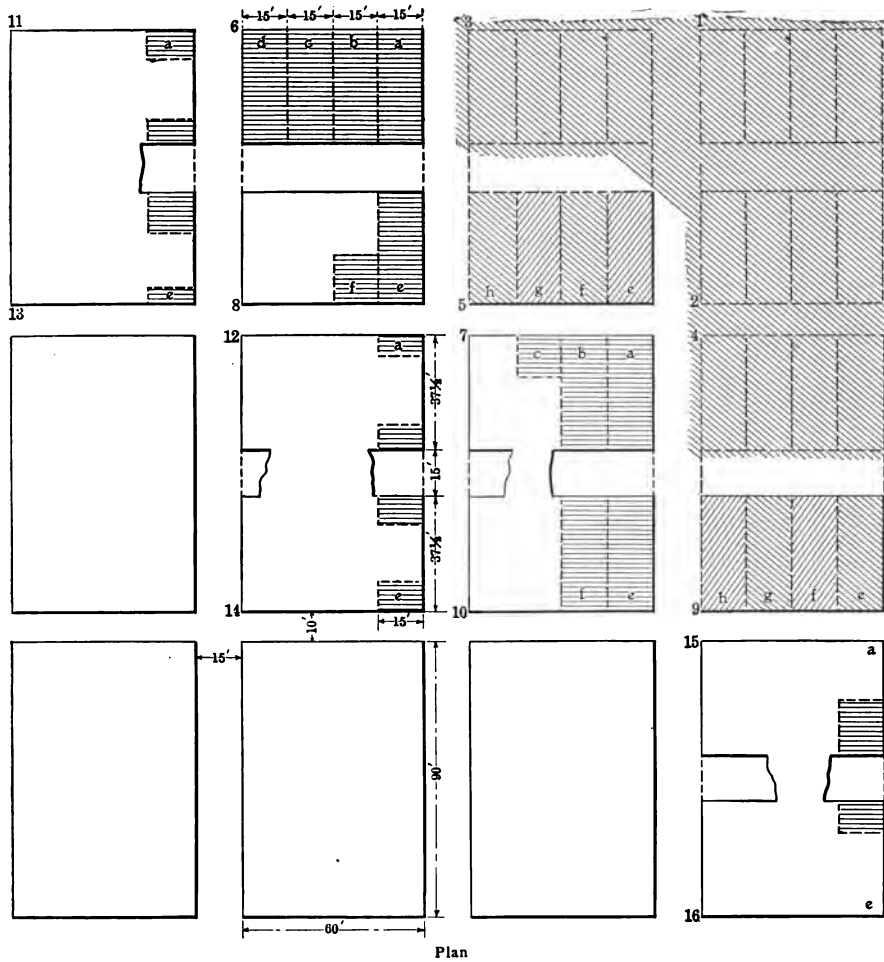

FIG. 31. — Pillar Robbing.

pillar 8, *f* has also been started from the heading. In pillars 11 and 12, lanes have been started from both the center lanes and from the headings. In pillar 15, the center lane has been driven far enough to allow starting a lane in either direction. Four feet of hight is maintained throughout the seam. The timber is nearly all recovered, except in roadways.

This system of center laning first, may also be used under conditions where the roof is poor, but then the coal is only attacked from the center lane outward. It is a system often used in Durham, England. By center laning, assuming that the adjacent pillars toward the boundaries are down, working outward from the center lane, there is solid ground behind, whereas working from the heading toward the center lane the goaf would be behind, and in such a case it would be more difficult to keep up the ground while the pillar is being robbed.

Device for speedy landing. — Attention was attracted to a neat arrangement at the shaft mouth. Two tubs, end to end, are raised at once in the cage deck, and the track on the platform is laid in two lengths. One set, from one end of the cage to the center, is spiked in the ordinary way, and the other, which is a continuation of the first set, is hinged where the two sets join. The second set is not spiked down, thus it is free to move in a vertical plane for a few inches, having the point where it is fastened as a pivot. The cage rises in the shaft and passes the chairs at the landing in the usual manner, when it returns to take its position of rest at the landing and on the chairs which are standing out. At this moment the ends of the disengaged second set of rails come in contact with a lug placed at the proper point on the chairs on this side of the shaft, and this lug, coming in contact with the base of the rails, causes them to rise, and an artificial grade is produced on the cage car rails. The rear car, being raised on a slight incline, aids materially in drawing both cars off the cage platform. This arrangement could also be used where there is but one car. Either the back trucks of a single car could be raised in this manner, by having the track on the cage in two sections, as above, or the entire length of rail could be raised, one end being secured.

Wire rope guides were used in this shaft. The shaft is 18 ft. in diameter. Fifteen feet below the collar of the shaft, the angle on the corners of the cage engaged in wooden guides by means of which more steadiness was effected at the landing. Dogs are not so generally used in England, the tendency being rather to have more rigid examination of the cables than faithfully depending on the dogs to make up for deficient examination of the hoisting rope.

CHAPTER X. — WATNALL COLLIERY, MIDLAND DISTRICT

A 5 to 6-ft. Seam of Coal is Mined by the Longwall System. Two to four ft. above this Main Seam Lies a Thinner Seam of Useful Coal which in the Roadways is also Recovered.

THE Eastwood Colliery Company, in the Midland district, England, operates five collieries, one of which, known as the Watnall, lies near a town called Kimberly, reached by both the Great Northern Railroad and the Midland Railroad from Nottingham.

The seam mined at Watnall carries from 5 to 5½ ft. of steam coal, above which lies a 2- to 4-ft. strata of clayey material called clanch (Fig. 32). Above this is 2 to 3 ft. of softer coal called comb coal, or bright,

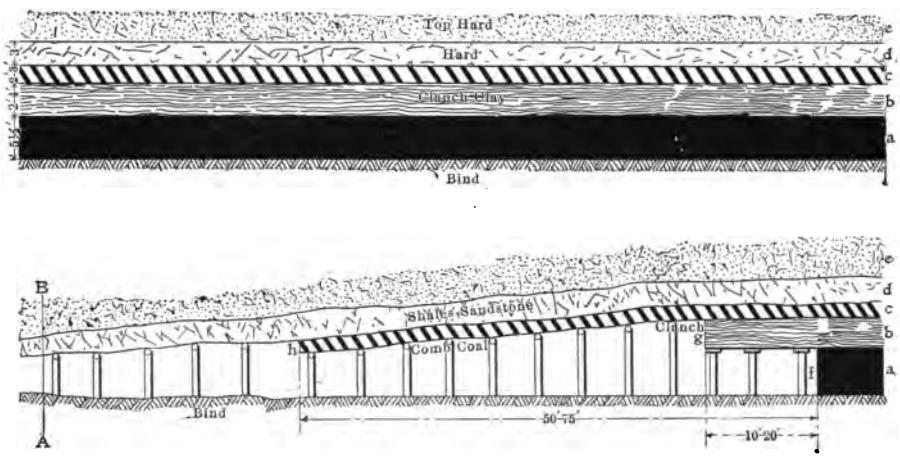

FIG. 32. — Lowering of Roof and Roof Coal Behind Longwall Face.

which is useful for household purposes. The average cover above the coal horizon is 960 ft., consisting of comparatively hard shale; then follow limestone and red sandstone. Below the seam is a rock called "bind," and several thinner coal seams at various elevations which, though not worked to-day, will probably be minable in the future.

SHAFTS

There are three shafts on the property. The head-frame over two of them is shown in Fig. 33, the hoisting arrangement being similar to

that at Seaton-Delaval. The shafts are 11 ft. in diameter, and are brick-lined throughout. Fig. 34 shows a landing at one of the shafts, with a

FIG. 33. — A Single Head Frame Over Two Shafts.

FIG. 34. — Landing Cars on Top.

double-deck cage loaded with four cars of 1400 lb. capacity each. The men are drawing the cars off the cage by means of hooks, which they engage in eyes attached to the car body. Note the iron gate, *a*, which,

running on a track, is raised when the cage ascends. There is but one compartment in the shaft, and on the down-trip in this shaft a load is being raised in balance up the other shaft, but a short distance away. In the mine a great part of the haulage is accomplished on self-acting inclines, graded 1 to 16. At the head of an incline was placed a friction controller brake, and hemp rope was used between the drum and the ribbon of the brake instead of wooden blocks of a particular texture, as ordinarily used for this purpose. Eighteen cars were operated in a trip.

At the station at the bottom of the shaft the grade is laid steeper, and the empty cars approaching the shaft are held back by an interfering block until such time as the cage is at rest, when this block is depressed mechanically and the cars, with assistance, make for the cage and are readily placed thereon.

Method of Mining

The method of mining employed at Watnall is longwall advancing. A pillar about 200 yards square has been left to support the shaft. The system involves running gateways about 120 ft. apart, and manipulating the longwall face between these gate roads, cross-gates being run at intervals according to requirements.

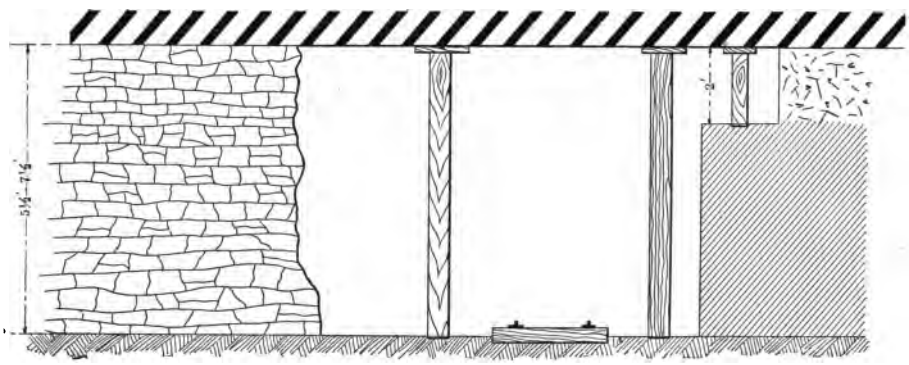

Fig. 35. — Timber Arrangement and Packing at Longwall Face.

Depending on the thickness of the clanch between the main coal and the comb coal, the seam is either undercut and the coal broken down, or, where the clanch is not too thick, this material is first cut out and the coal broken afterwards (Fig. 35). On the tall posts in the figure rests the comb coal. Behind the face there is continual subsidence of roof on the packs. These packs are built with rock broken from the clanch, brought forward as the work progresses. Packs are built 12 ft. wide at 12-ft. intervals, so that 50 per cent. of the coal area is replaced.

The clanch is brought down as close to the face as possible, when tall posts are set to support the comb coal. The comb coal is won only in the gateways, the packs being set up to the clanch (Figs. 35 and

36). Behind the comb coal top-shales or sandstone makes its presence felt in the course of time. Supposing that the main coal is 5½ ft. thick, and clanch and comb each 3 ft. thick, there will be 11½ ft. of cutting altogether before the top shales are met, and if the gate stands any length of time it is probable that an additional 3 ft. of cutting will be necessary, due to the plunging up of the floor, and the further subsidence of the roof.

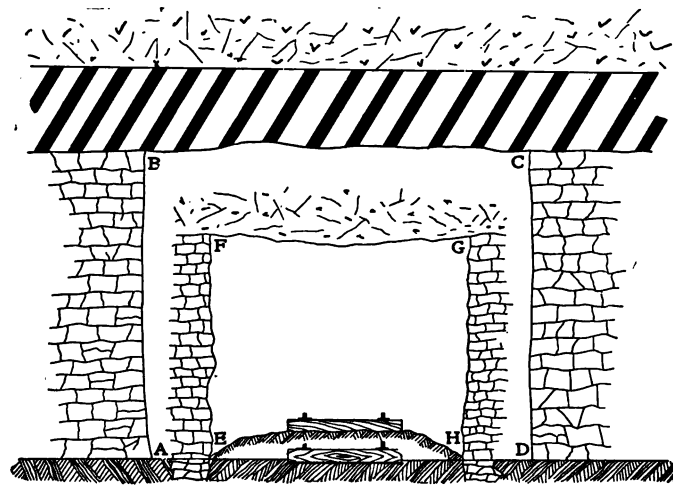

FIG. 36. — Upheaval of Floor and Subsidence of Roof Showing Shrinkage of Road Area.

The action of the floor and roof in removal of seams by longwall is interesting. Describing a floor as "soft" does not necessarily mean that it is a clay. Quite to the contrary, it may be a consistent sandstone not readily broken up. A result of roof pressure on the floor is shown in Fig. 36, showing the effect in the gateway after it had stood for a long period. *A, B, C, D* is the original form — *E, F, G, H* shows the form of the gate after the various pressures had exerted themselves.

Behind the face are usually two rows of timber (Fig. 35), one close to the coal — which at times is omitted — and another 5 to 6 ft. back; cars run between the two. This road communicates with the cross-gateways and finally the main haulage-way, which communicates with the shaft over a mile away.

The timbers at the face are practically all withdrawn. The blocks of ground are let to a contractor who is responsible for the stalls he is working. Should he fail to recover timber where the roof is known to be good, his monthly settlement is likely to show reduction. The average wage in the camp is 7 to 8 s. per shift of 8 hours. Contractors get 2 s. 8 p. per ton of coal won, inclusive of timbering and pack-wall building. They are paid extra for ripping, and the company removes the coal from the face.

CHAPTER XI. — COAL MINING IN SOUTH STAFFORDSHIRE

Mining the Ten Yard Seam. Constant Exigency of Fire and High Backs Involved in a Dangerous Method of Mining

TYPICAL operation of the South Staffordshire method of working a thick coal seam was first observed at the Sandwell Park colliery. This mine is located in the heart of the South Staffordshire district, the county of Staffordshire, known as "Staffs." The nearest town to the colliery is Smethwick, located on the Northeastern Line from Birmingham, some 10 miles distant.

Birmingham is the fourth largest city in England, and is located in the northwest corner of Warwickshire. It is eminent as a manufacturing town for the production of all kinds of iron, brass, and metallic wares; coming after Manchester in importance as an industrial center. Passing from Birmingham to the northwest, there is a succession of iron manufacturing towns, and coal mines are seen continuously along the route, which shortly passes into Staffordshire County. The district is locally called the "black country," but the atmosphere and surroundings hardly bear out the fairness of this name.

Some of the largest coal plants in the country are located in this vicinity, and recent new discoveries of extensive coal beds have brought in capital for the erection of modern plants, typical of the English policy in regard to permanency. The coal bed in this district is generally known as the 10-yd. seam, though this thickness is not general. At the Sandwell colliery, for example, the average thickness approaches 14 feet.

To summarize the method of mining in a general way. Roads are usually driven out to the boundary, and the operation of mining is accomplished on the retreat on a series of blocks of coal, separated one from the other by ribs or narrow pillars. Within these ribs, small, square pillars are left for the support of the roof. The first work is done in the bottom 6 ft. of coal, and the top coal is won by cutting what are known as spurs into the roof between the pillars; in this way the coal is brought down slice by slice with the assistance of light powder shots. This method is also used in certain parts of India, whence a number of South Staffordshire workmen have gone. There the roof and floor are of a hard sandstone.

The Sandwell Park Colliery

At Sandwell Park, they have 10 ft. of material called "bind," lying over the coal. Above this bind are successive layers of red and gray sandstones with intervening coal seams and shales. Eighty yards from the surface is an unworked seam 3½ ft. thick, called "brooch," which has exceptional qualities for household purposes, and seems to bear similar characteristics to the comb coal at Watnall colliery.

The main coal is worked to a depth of approximately 1260 ft. at Sandwell. This is not a maximum for the district, where some very speedy hoists have been erected by the Allis-Frazers Company for lifts up to 2000 feet.

Fig. 37. — Surface Plant Showing Cultivation in Foreground in Spite of Severe Subsidence.

A general view of the Sandwell Park colliery is shown in Fig. 37. In this illustration, notice that cultivation does not seem to have suffered much as a result of the subsidence. The three pits, head-frames of which are noted in the figure, are about 200 ft. from one another. Two of the shafts serve as downcasts. All three pits are circular and are brick-lined throughout. The center head-frame is of steel design, being of latticed girders. It is 60 ft. high from base to sheave wheel shaft, 28 ft. center to center of legs, and 52 ft. from center of back-stay to near upright leg.

Rope guides are suspended in one of the shafts. Only three of the ropes are used for guides in each compartment, two on one side, and one in the center of the other side. These ropes are 1½-in. in diameter, and of single-wire strands. The ropes, which are weighted at the bottom of the shaft, are free to meet the changes of length induced by variance in temperatures. Within 15 ft. of the collar of the shaft, timber guides are placed which insure steady landing of the cage. Aside from the

guide ropes, on which the two cages run, the shaft is clear below the shoes above mentioned.

Weights are not always used for keeping the ropes taut. In a deep shaft, as much as 7 or 8 tons may be required to properly stretch and hold the rope. This involves more or less space, which may be ill-afforded where sump room is limited. A number of mechanical devices have been employed for holding the rope in place. It is, of course, extremely desirable that the ropes be held perfectly taut, and they should not twist. Mysterious accidents due to cages coming in contact with each other in the shaft during flight are not unheard of. The cages are double-deckers, each deck holding two cars end to end.

Catching Water in Shafts

The matter of water in shafts has received careful attention in the South Staffordshire district. Water rings, or what are called "garlands," are set at intervals in the shaft. These act as receptacles for the water, which is conducted down the shaft from these reservoirs in small pipes, to join the body of mine water in the sump.

There are a number of forms of water rings set to encircle the inner part of the shaft lining. The common form is simply a groove-like depression in an iron casting, which is set in the shaft lining. Above this the bricks are trimmed inward, so that the water in running down the lining is conducted to the groove, from whence it drains to a common point where a tube connects, and the water which has found its way into the groove is conducted down the shaft. This form, however, has not proved so desirable because of the accumulation of small particles of refuse necessitating a frequent cleaning out.

Another form of water ring often seen in the Staffordshire district appears to serve the purpose well. In sinking a circular shaft in moderately hard formation, what is known as a "curb" is placed at certain intervals in the course of the sinking work. By way of explanation, this curb is simply an annulus which may be of timber or metal, and is divided into a number of segments fastened together to complete the circle. This device performs practically the same duties in circular shafts as regards holding the lagging in place as our square shaft sets do in America. It may be stated here that the square shafts are as rare in Europe as circular shafts are in America.

The Construction of a Curb

Vertical stringers are placed between the curbs to act the same as our hangers. In setting these water accumulators, an ordinary curb is set in the usual manner, see Fig. 37A. Two or three courses of brick are now set on the curb as shown at *b*. A wooden piece *c*, made of flexible plank

about 2 x 8 in. and having a ledge *d* cut on the top, is now set on end and fastened to the curb *a*. This is so arranged that the outer edge of lip *d* is flushed with the inner line of shaft.

Resting on this ledge *d* and on the bricks *g* is set a series of bricks *x*. Thus an archway *e* is formed, in which space the water accumulates. These latter rows *x* are placed at intervals, leaving a space of 4 or 5 in., as shown by *f*, in Fig. 37A. In this way the water coming down the shafts finds its way into the reservoir *e*. Above the rows *x* a second curb is placed, *d*, the top edge of which makes the original width to the lining. The shaft from that point on is again of the original inner diameter.

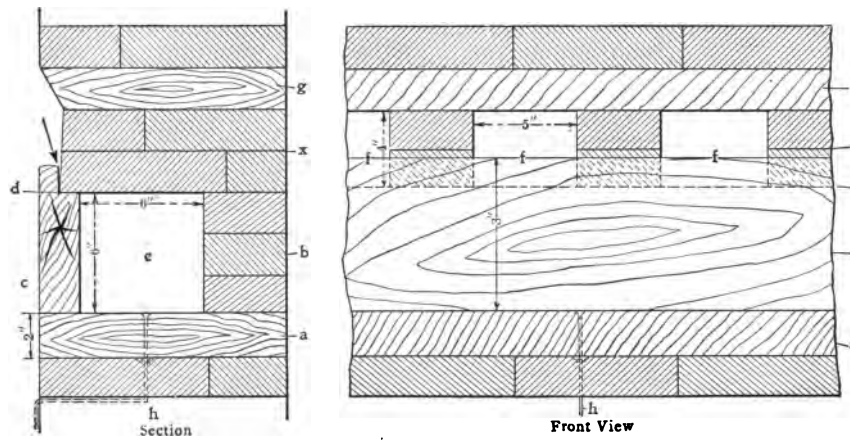

FIG. 37A. — Water Accumulator in Shaft.

At *h* is shown the pipe, which is simply a small pipe for conducting the water from the reservoir down the shaft, either to the next garland, or else, if it is the last reservoir, to the sump. Behind the brickwork ashes or puddled clay is packed, and all joints between the curb and the brickwork are made tight.

STEEL TIMBERING AT SANDWELL

The prevalent use of steel underground was noticed, but as elsewhere, the use of this material is more for girders than for any other purpose. It is generally used in England, to replace timber caps only, wooden posts being retained.

Where heavy pressures have to be counteracted, the use of steel girders has proved economical; instances have been noted where timbers have been necessarily changed two or three times, within short intervals. The first cost of steel is, of course, much greater, but under certain conditions the final cost has been found to be less.

At Sandwell, steel is used considerably in the stations, and also on

main haulage-ways. Where a side pressure is to be counteracted, a shoe is shrunk on the beam at the point where the beam rests on the edge of the post. This shoe fits around the lower flange of the girder and butts up against the post. The girder used weighs about 66 lb. per yard, and has a 4 to 5 in. web and flange. A one-half inch thickness of metal is adopted for an 8-in. span.

Controller Device

A device has been installed whereby the engineer on a haulage motor is restrained from throwing the controller at full speed in a sudden manner. On a motor controlling the haulage on an incline, the controller wheel was engaged with a thread gear so pitched that the movement of this screw effected only a gradual throwing out, or in, of the resistance. It was impossible for the engineer to move his controller with sufficient speed to cause a burning out of the motor. It was so arranged, however, that while the engineer could only throw out the resistance in a gradual manner, he could throw it on in its entirety at any moment, should a sudden stop be necessitated. In this way common labor could be employed at these stations, where formerly a higher priced man was required.

It may be remembered that one of the chief features of the South Staffordshire mines to be reckoned with is the gas, which rapidly accumulates in this formation. On this account, more than any other, perhaps, is due the system of mining whereby these rectangular sides of work are shut off one from the other in the progress of the work.

In working the South Staffordshire beds there are three distinct stages of operation. The first is the getting of the coal in the manner previously described. The second is the winning of the coal in pillars and ribs, and the third is the recovery of coal left in the second stage. In the third stage, the work is carried on entirely through broken ground.

Many years may elapse between the operation of these various stages. The third stage, for example, may be an attack on a mine which has not been operated for 50 years, and where coal hitherto not of sufficient value may now be extracted with profit.

That the South Staffordshire system of mining involves danger is beyond question. The number of accidents due to falls of roof is very large. The system requires a great amount of skill, and could not be successfully operated by miners acquainted only with the ordinary coal methods. In this section the men have grown up with the system, and in spite of this, only the ablest are employed in getting down the roof coal.

Handling 30-foot Timbers

In a 30-ft. seam, about 24 ft. of coal will be brought down by dropping. Timbers sufficiently high to hold up this roof in working places, must naturally be employed, and the handling of timbers underground of 30 ft. hight in an expeditious manner is an art in itself.

There is no better evidence of the fulfilment of the duties of these timbers than seeing the roof fall as soon as they are removed. Fig. 38

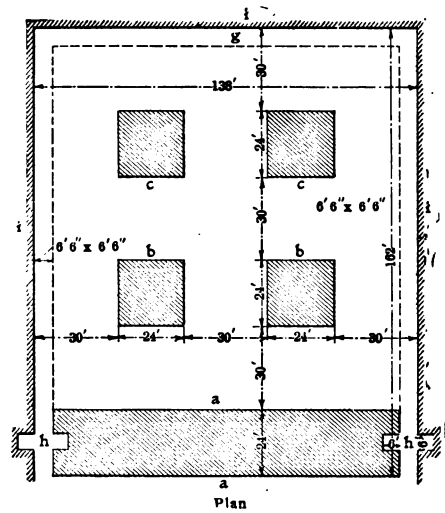

Fig. 38. — A Side of Work after First Stage has been Completed.

shows a side of work, the first stage having been completed. The original roads are outlined by the dotted lines *i i i*, and are the ribs which encircle this work. Fig. 39 shows the pillars being formed and work of extraction in the intervals. The section on Fig. 38 shows the completed side of work before withdrawal of all timbers. Fig. 40 shows a similar condition as exists in the section illustrated by Fig. 39.

The white cross to the left of the man's head in Fig. 40 shows the corner of a pillar, similarly as at *X*, in Fig. 31. Note the timbers supporting the upper coal. The photo was taken at a point shown at *f*, Fig 38, where there was 20 ft. of space overhead, the roof having begun to destroy itself, following removal of timbers. In Fig. 40, above the white cross *X*, a spurn would be holed, and on removal of the timber seen in the illustration, a considerable amount of coal would be brought down with the aid of light shots.

Measures Anticipating Fire

To meet the constant exigencies of impending fire, sides of work are so arranged that they may be cut off at any time. At soon as fire breaks

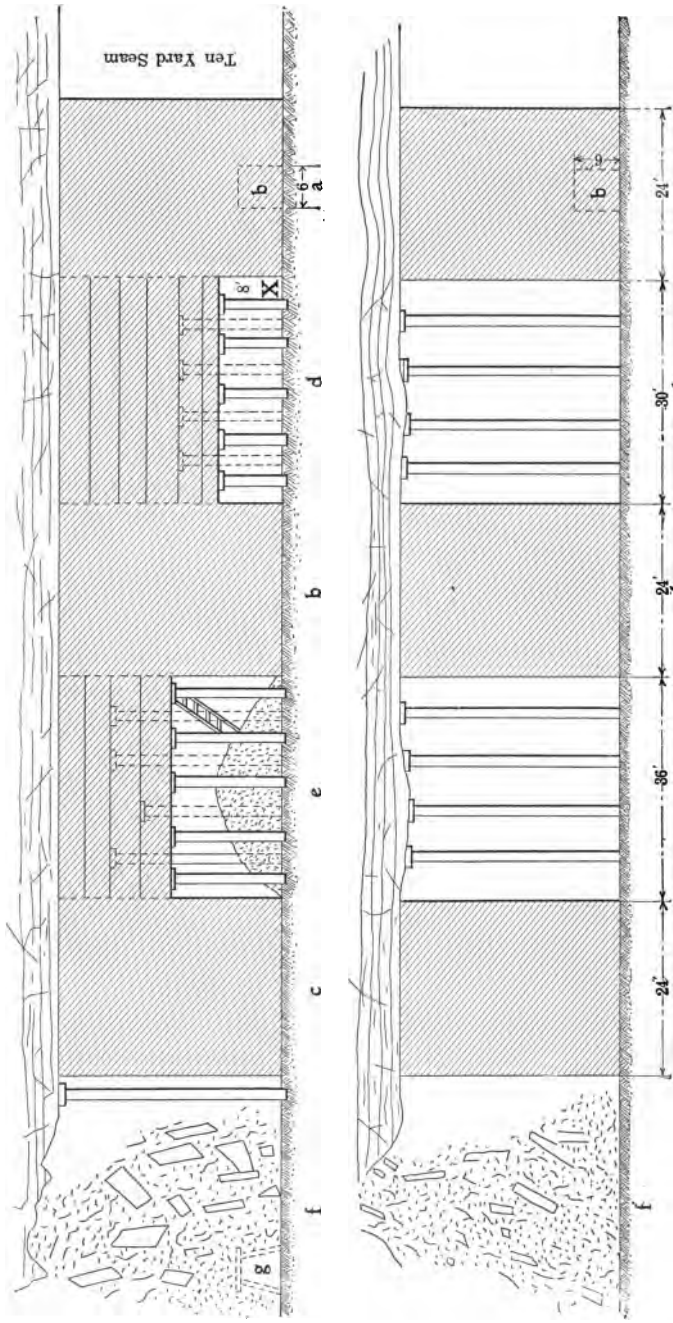

Fig. 39. — First Mining of Coal by Dropping Method and Formation of Pillars.

The Seam was Mined 100 Years Ago

In the Delph mine, coal was mined 100 years ago, but then only the best of it was taken, so that now the work is largely the recovery of coal not marketable in those days, which at the present brings in a profit. At a lower level in the same property, clay is being mined, and is used for burning into bricks.

The coal seam is far from clean; there are innumerable bands of shale, etc., each of which is recognized by the natives and given a name. Where a band of stone becomes thick, the method of getting the coal is to first mine out under the stone band, support this roof with timber, and withdraw this timber after the coal in an area has been removed from under; now dropping this stone and standing on the fallen ground to attack the coal above.

The Top Fence

A very neat form of top fence is used, shown in Figs. 42 and 43. The design is two upright stepped posts, on which rest four boards. First, the shortest board rests on the bottom steps of the posts; second, the next longer rests on its step, etc. The vertical movement of these boards is governed by the light rope guide, which passes through holes at each end of the boards. In Fig. 43, the cage is at the landing and has raised the gate. In Fig. 42, the cage has started on its trip down the shaft, and parts of the gate are taking position on the steps of the posts. On the opposite side of the shaft is a similar arrangement.

Parkhead Colliery

Third Stage. — In the third stage of the South Staffordshire method of mining, the major part of the coal seam is practically drawn. The pillars have been removed as far as possible in the first and second stages, but there is considerable pay material left to be mined by the man who is after a moderate profit with reasonable outlay. The Parkhead colliery is situated at Brierly Hill, a few miles from the seat of the Delph operations.

Fig. 44 shows the arrangement of the surface plant at this mine. The shafts are uncommonly close together. One hoisting-engine drum serves both shafts, the balance being effected between the two cages. The purpose for having the drum outside in the hoist house appears to be to simplify construction, and economize on building material, as in this way a small engine house is required. It is not infrequent in South Staffordshire to see two shafts several hundred feet apart operated by one engine, which may be placed midway between the two shafts, the hoisting ropes being held in position at intervals by light timber frames and idler pulleys.

The miners drink a peculiar kind of beer, which is brought to them at intervals. As shown in Fig. 40, the men often work stripped from the waist, but do not seem to suffer from the unusually warm conditions.

In gathering the coal to be loaded into cars, shallow baskets are commonly used in this district. They are made of wicker work, or some light metal. Coal is raked into the basket by means of a short-handled wide-toothed rake, or with a scoop. It is claimed that with these baskets a man loads considerably more than he could with a shovel, especially where the floor is even. Certain it is that he makes fewer movements from the floor to the top of the car by this method, inasmuch as the baskets hold several shovelfuls.

Delph Colliery

Second Stage. — With a view of investigating the second working of the South Staffordshire coal, the Delph colliery was visited. This is in the same district as Sandwell Park, near a place called Breattle Lane, on the Northwestern line.

In reviewing the first stage of work of the South Staffordshire method, the pillars are supposedly standing, but the roof between the pillars has now a tendency to fall, as practically all the timbers have been removed. The pillars are not necessarily the original size as cut in the first work, because very often an attempt is made to remove them during this first work, though a complete removal is rarely effected. The ribs of coal would not be touched in the first working. Finally a condition of thoroughly packed areas exists around the pillars, as shown in Fig. 5. In the course of time this material solidifies to such an extent that the work of passing through it presents quite the same conditions as the original coal did, though this extreme condition does not obtain until the ground has been allowed to rest for a long time. It may be 20 or more years between the time of first and second working. Nearly all the timber is removed in the first working.

To regain the ribs and pillars, roads $6\frac{1}{2} \times 6\frac{1}{2}$ ft. are driven through the ribs, which latter are 24 to 30 ft. wide. When the back rib is met, roads are started and driven in this back rib until they meet. Then working on the retreat, the operation of taking the rib is carried on. In the meantime, from the side ribs, roads are driven through the fallen ground to cut the point where it is known that the pillars or stumps are standing, though perhaps in more or less shattered condition.

The work of taking the rib of a pillar is then carried back. Pillars are removed in the ordinary way by undercutting, setting up posts, and finally, intelligent removal of the posts with ensuing fall of the coal from the upper part of pillars.

the ground is worked out. Control of air circulation is quite difficult with means at hand, and in this case was extremely poor. The returns from this kind of work are not prodigious. The work is usually carried on by lessees, who, as a class, are not prone to elaborate outlay.

FIG. 43. — Cage at Landing, Gate Raised.

The air current in this particular mine was stimulated by the dropping of water down one shaft, a jet of steam being passed up the other. Ventilation is at its best very poor and the presence of black damp was pronounced during my [illegible] only with great difficulty that a working place could be [illegible] ought the loose ground, foresight-[illegible] 50 inclusive.

[illegible] have been set and spiling is [illegible] the laggings, [illegible] are set behind [illegible] angle of about 15 deg. pressure.

FIG. 44.—Leaser's Surface Plant — Drum Outside of Hoist House.

FIG. 45. — Last Stage of Work. Forespiling through Packed Ground.

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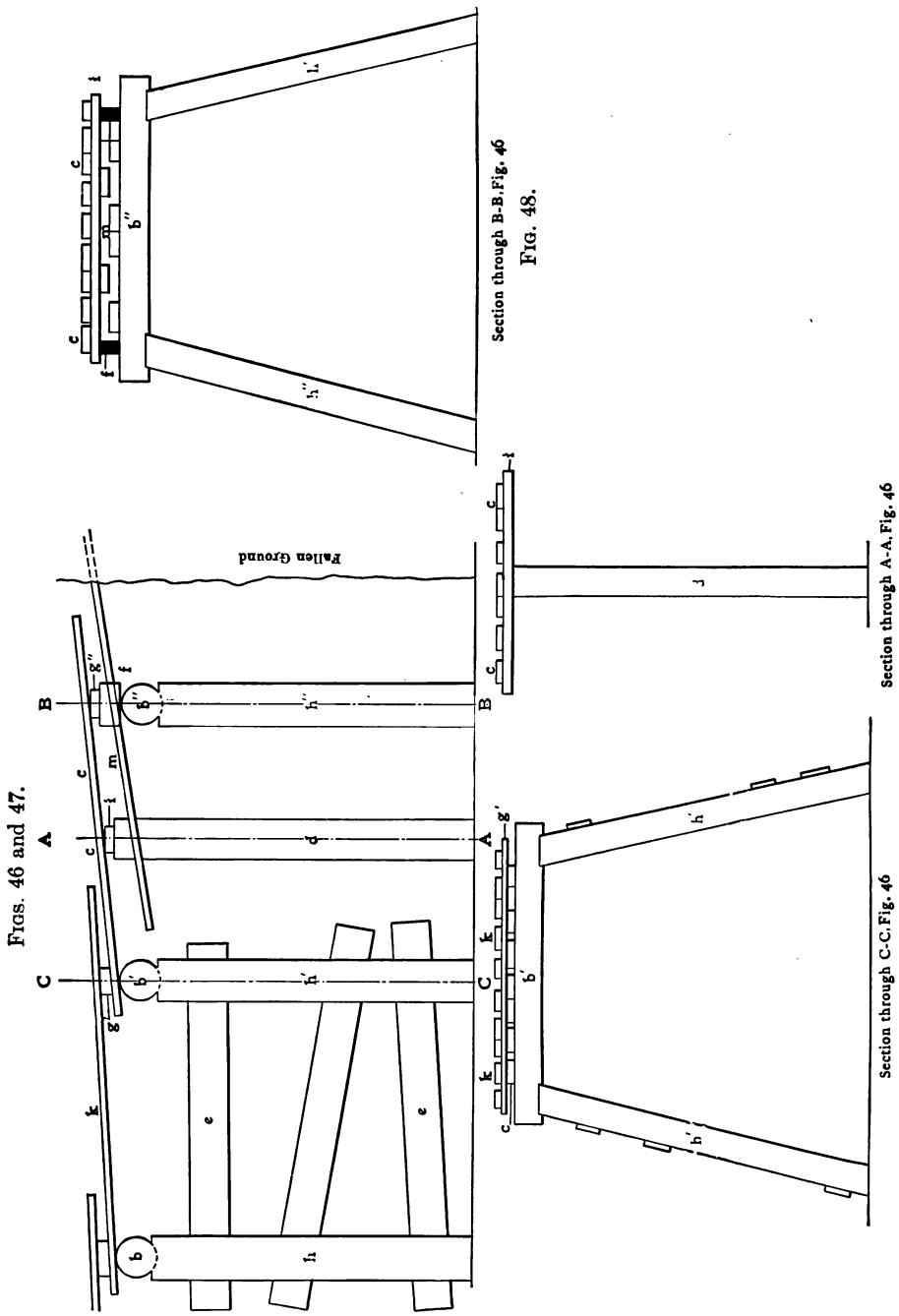
FIG. 43. — Cage at Landing, Gate Raised.

The air current in this particular mine was stimulated by the dropping of water down one shaft, a jet of steam being passed up the other. Ventilation is at its best very poor, and the presence of black damp was so pronounced during my visit that it was only with great difficulty that illumination could be maintained; certain working places could not be entered at all on this day. In driving through the loose ground, forespiling is resorted to, illustrated in Figs. 45 to 50 inclusive.

Referring to Fig. 46, post and caps of *c* have been set, and spiling is being pushed forward over set *B*. The side laggings, *e*, *e*, are set behind *h*,' and are driven slightly outward at an angle of about 15 deg. pressure,

FIG. 44. — Leaser's Surface Plant — Drum Outside of Hoist House.

FIG. 45. — Last Stage of Work. Forespiling through Packed Ground.



FIGS. 46 and 47.

FIG. 48.

FIG. 50.

FIG. 49.

Detail of Forespile Timbering.

soon bringing them against the posts. An auxiliary post, *d*, has been set with a plank, *i*, above the post. This arrangement is seen in detail in Fig. 50. It serves to support the projecting spiles, *e*, *e*, of the previous set, and is intended merely for temporary support.

Frame *B*, being in position, two bricks, *f*, *f*, shown in both figures, are set at the end on the cap *b*,'' and a plank bridged over the two bricks, thus allowing free space for the cross-spiling *m*, now to be driven. One man picks at the spiles *m*, at the face, which is remarkably solid, making space for insertion, while another man hammers the spiles at their end to drive them ahead. When these spiles have been driven their length, the brick supports are removed, allowing the bridge *g''* to lower, with its row of spiles, *c*, *c*, over it, finally coming to rest on the cap, *b''*. The auxiliary post, *d*, and its cap, *i*, having been taken down in the meantime. This method of forespiling is different from that ordinarily seen, in that the spiles do not occupy headroom under the cap of the set. Compare with Fig. 3.

CHAPTER XII. — SPAWOOD MINE, YORKSHIRE

A 7½-ft. Flat-iron Ore-bed is Mined by the Room and Pillar System and the Pillars are later Robbed, High Extraction of the Deposit Being Effected.

THE Spawood Mine is situated on the outskirts of the town of Guysborough, Cleveland district, Yorkshire, Eng. The mine is owned by Sir B. Samuelson & Co., and is reached by the Northeastern Railroad.

GEOLOGY AND ORE

An ironstone, averaging 7½ ft. in thickness, lies on a gradient which approximates 1.4 per cent. This ironstone bed is typical of the well-known Cleveland district, though not as clean as is often found. A band of slate, attaining a very hard texture, is bedded with the ironstone, and has to be disposed of before shipping the broken rock.

Above the seam is a material called "dogger," which may be two feet in thickness. Where this material is soft, it is found best to bring it down with the ore, rather than to maintain it with timber. This dogger is an ironstone of inferior quality, and rather a hard clay of more or less uniform texture, as compared to the oolitic structure of the ironstone proper. The age of this formation is Upper Lyas, Triassic. At a number of the mines in Cleveland the dogger is rich enough in iron to warrant its being called ore. The average iron content of the ironstone at the Spawood Mine is 28 per cent.

The formation overlying the seam is far from soft and, in certain parts, very strong. A typical section of the formation overlying the ironstone would show a stratification of dogger and shale of varying textures, with dogger balls in the upper part. Approaching the surface, alum beds are encountered, with rather soft sandstone stratifications. The upper 16 ft. is clay. Fossils are plentiful.

The following section is typical of the formation at this mine, the measurements being made from the surface. Clay, 16 ft.; sandstone, 36 ft.; alum shale, 180 ft.; hard nodules of shale, 182 ft.; hard shale, 216 ft.; dogger balls, 222 ft.; jet shale, 234 ft.; soft shale, 252 ft.; dogger and hard gray shale, 270 ft.; soft shale, 282 ft.; dogger, 284 ft.; ironstone, 291.5 ft.; black shale, 294.5 ft.; inferior ironstone, 297 ft.; — and the shale bottom.

The formation outcrops on the hillside, so that the amount of cover over the seam is variable. This cover is sometimes as great as 700 ft.

As a result of mining out this seam, which is done without replacement at the Spawood mine, surface subsidence is complete at all points.

Drilling and Firing Holes

The ironstone is never too hard to drill with the rotary hand augur. A form of drill generally used is shown in Fig. 51.

Fig. 51. — Method of Setting Up Hand Power Drills.

Placing both hands on the drill handle, it was found that no great amount of energy was required to actuate the rotary motion of the augur. I do not believe there have been any serious attempts made at introducing air drills in these mines, and am inclined to believe that while the management realizes their practicability, it hesitates at the introduction of a plant, which, due to the extent of the mines, would have to be elaborate.

Holes are fired immediately after being drilled. Several holes may be drilled one after the other, but only one can be fired at a time. There are certain laws which govern this. Black powder and ammenol explosive are used. The explosive does not create much smoke, and the miner can safely return to the working place a short time after firing the shot. While several holes may be drilled previous to the firing of a single one,

the miner usually prefers to drill a hole, fire it, and then decide as to the position of the succeeding shot. From a standpoint of powder economy, this plan appears good. The result obtained in firing a number of shots simultaneously is not always a good measure of what the requirements may have been.

In drilling these holes no water is used. One half to one pound of powder is used per charge. Powder costs 4 p. ½ penny per lb. The powder cost per ton of rock broken is given at 2 p. ½ penny. This is for black powder which is used wherever possible. It is endeavored to avoid shattering the rock as much as possible, for the smelter rules out small sizes in buying the ores.

Method of Mining

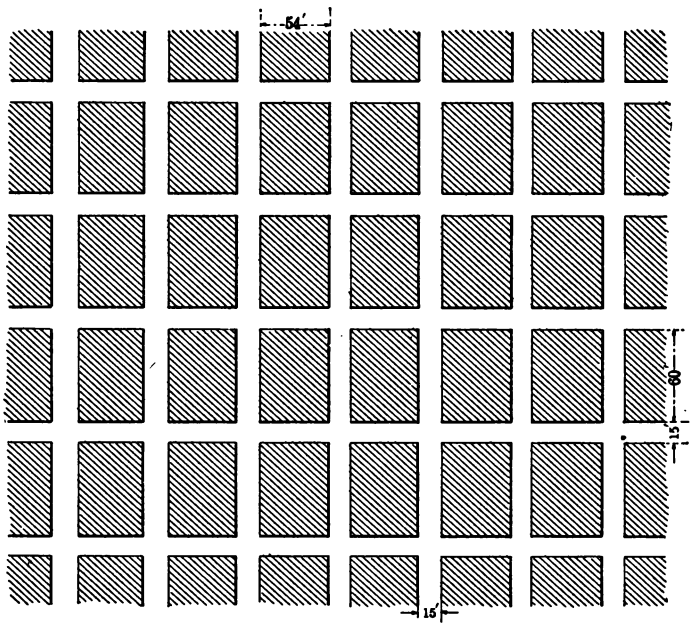
The method of mining is the bord-and-pillar, similar to that used in coal mining. In this mine the main heading has been driven about 6000 ft. in ore, all rock being delivered from the branch headings to this main heading. Two thousand tons are being hauled daily in cars of 1¼ tons capacity which run on 2½ ft. gage track. Rope haulage is the motive medium.

Large areas have been blocked out in a manner similar to that in Figs. 52–55, and while advance work continues, called "whole work," pillars are also being removed; this, in contradistinction, is called "broken work," as at Seaton-Delaval. The policy at present is to drive all headings, blocking out pillars, to a width of 15 ft.; pillars being 54 x 60 ft. The work in the seam is very regular, and thoroughly planned before ground-breaking commences. In the whole work, the bords are driven in a straight line, and at the proper regular interval cross-bords are driven, two men working in a place. With a 15-ft. drivage over these large areas, it is seen that a large tonnage is available simply in this work, which ordinarily would be called development work, and it is quite easy to maintain the desired tonnage in the accomplishment of this "whole work."

In driving in the headways, one side of the breast is usually carried in advance of the other, so as to always break to a free side.

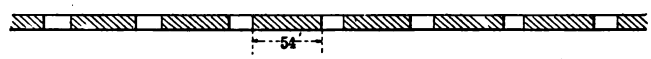
In the broken work, robbing can be started anywhere, provided the proper precautions have been taken for the maintenance of roadways. The undesirable hang of large areas of roof is met with here, with eventual sudden fall. After the first break, the roof follows along and is held intact readily with 8- to 10-in. timbers.

Vertical fissures and horizontal stratifications are distinct throughout the mine. The former condition is considered desirable by the miners in the "whole work," for, in breaking to a vertical plane in the heading, powder breaks to the best advantage.



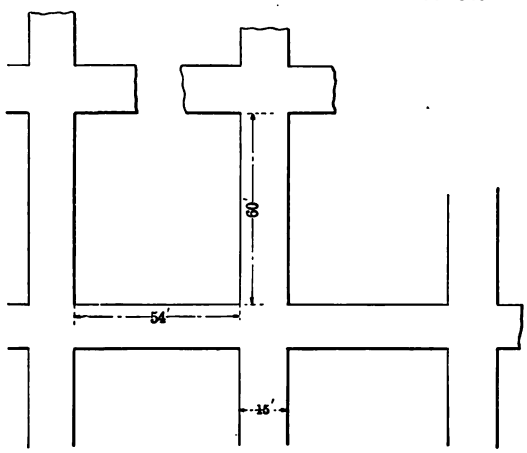
Plan

FIG. 52.



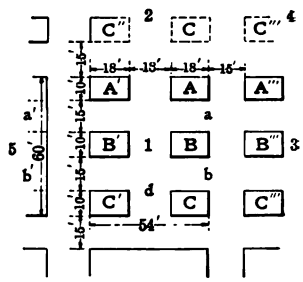
Section

FIG. 53.



Plan

FIG. 54.



Plan

FIG. 55.

General Plan of Working and Pillar Robbing.

Robbing the Pillars

The work of robbing the pillars is carried on very much in the same way as in coal mining. An angle approximating 45 deg. is aimed at as a line of retreat. Stumps of pillars are left to assist the timbers in preventing falls near a working place.

Each individual pillar is robbed in a similar manner. It is divided into squares (Fig. 55), two cross-headings, *a*, *b*, usually being driven 15 ft. wide parallel to the long end. In Fig. 55, *A'* of pillar 1 is being removed; *B* is also under fire, and also *C'''* of pillar 3. In short, the parts of each pillar are manipulated in a similar way as the pillar as a whole is manipulated, as compared to its neighbors, the aim being to keep the retreat on the oblique.

Fig. 54 is an enlarged plan of the whole work. In the broken work, timbers are kept close up to the face, the requirements of the law being very strict in this regard. The main falls follow the work, timbers and stumps of pillar controlling the situation.

No general rule can be given for this kind of work. Timbering is built up following the miners' judgment, and is usually used in amount greater than actually necessary to meet requirements. The aim is to keep the roof up until ready to abandon the place, and recover the timber as far as possible. It is undesirable to have the roof take weight too heavily on the timbers. On this account the timber should be removed in an expeditious manner, and the place abandoned before a heavy settlement of roof has had opportunity to assert itself. Otherwise the timbers will have to be cut or shot out to effect their removal.

The greater part of the timber used is recovered, to be again utilized, though no definite statistics on this point were available. The ground breaks blocky, though in time the caves become compact until the ground is hardly recognized as having been once broken. It would be thought that where the cover approximates a thickness as great as 700 ft., subsidence would not be felt on the surface with this hight of stope.

The fact that subsidence is anticipated, and does occur at all points, is somewhat puzzling. I can only account for the condition from the fact that the rock becomes strongly compressed, though in a good many places there are no such indications. Where only a comparatively small area has been caved the subsidence was not noticeable, but as the area over which the pillars were being removed was enlarged, the effect on the surface became more marked.

Tramming

The ore is all trammed out of the mine in one shift, but mining is carried on during two shifts. The cars are filled to about a foot over the lip, the largest rocks being built up on the sides.

In order that cars excessively loaded may not pass out of the adit and up to the automatic cylindrical dumpers, a ring of iron is hung over the track at the proper elevation, to serve as a gage to measure the hight to which the cars may be filled that they may readily enter the cylinder.

The cars are dumped on reaching the portal of the adit, the rock falling upon a heavy impact screen. Material of 2½ in., or under, passes into cars and these are conveyed by rope haulage to the waste dump. The oversize is delivered to a shelf conveyer, 75 ft. long x 6 ft. wide. This conveyer consists of successive plates of ⅜-in. metal, each 12 x 72 in., and having 2-in. lips riveted at each end. The conveyer moves at a speed of 70 ft. per minute, electric motive power being employed. Along the length of this wide conveyer is a second conveyer 3 ft. wide, moving at the same speed and in the same direction.

To the left of the large conveyer is a stationary timber platform, which extends along its length. As the rock is dumped upon the screen, and the oversize finds its way on to the wide conveyer, the sorters walk up on the moving conveyer in opposite direction to the movement of the oncoming ore. Both conveyers and platform are at the same elevation. About 10 men are engaged in this work, and since tramming is all done in one shift, each man accounts for 200 tons of rock.

The inferior rock is thus sorted from the shipping ore, and thrown on to the 3-ft. waste conveyer, finally being delivered at the dump. Large pieces of fairly good rock are lifted from the conveyer and placed on to the stationary platform, to be cobbed when there is no ore on the conveyer to be sorted. The good rock left on the main conveyer passes on and is discharged at the end of its course into railroad cars.

CHAPTER XIII. — PARK PIT, YORKSHIRE

An 8 to 10 ft. Iron-stone Bed is Replaced by Rock Filling and Surface Subsidence thus Counteracted.

PARK PIT is situated at Skelton, Yorkshire County (Cleveland district). The western shore of the North Sea lies about 7 miles distant. Here the rolling character of the country is more pronounced than that in which the Spawood mine is situated.

GEOLOGY

The shaft was sunk centrally in a dish-like area which rises symmetrically on a 1½-per cent. grade. The formation here is similar to that of Guysborough, 5 miles to the eastward. The ironstone found at Skelton averages 10 ft. in thickness, and is clean. The shaft is about 350 ft. in depth, 14 ft. in diameter, and brick-lined throughout. Four 1¼-in. cables, weighted at the bottom with one-ton weights, serve as guides. The ironstone is overlaid with about 2½ ft. of dogger, then 30 ft. of shale of the ordinary variety, 66 ft. of jet shales with dogger balls, 75 ft. of dogger rock, 48 ft. of alum shales, and 138 ft. of shale with loam and bands of ironstone.

In one section a bore hole was being sunk where a very soft formation has caused much anxiety on account of subsidence. So far, bands of strong clay, loamy clay, sand, quicksand, and water have been encountered, the hole at the time having reached 75 ft. in depth. This formation is extraordinary, rather than typical of the district.

As mentioned before, subsidence is anticipated at all points with the average formation, but with the above the action, of course, is very much more severe. Inasmuch as the surface must be maintained as far as possible these conditions are undesirable. Since the seam is clean there is no refuse material to throw back and utilize for wall building.

MINING

The method which is now being experimented with to meet the problem is borrowing broken waste rock from different points in the mine, and building up walls to replace the pillars, so filling the entire area.

The work in this mine is now entirely broken, the limits of the property having been reached in all directions. Walls 12 to 18 in. thick are built at intervals across the headings between the pillars, at a 3-ft. interval. In order to build to the roof, which at times attains the hight of 12 ft.,

the work is done in steps. This scheme was in a more or less experimental stage.

Referring to Fig. 56, a 60 x 90 ft. pillar is under attack. The pillar is taken in 14-ft. lifts. At 3-ft. intervals, running the width of the 14-ft. lanes, 12 to 18-in. rock walls are built. Similarly walls are carried along the sides of the lanes. In the space between the walls small stuff is packed.

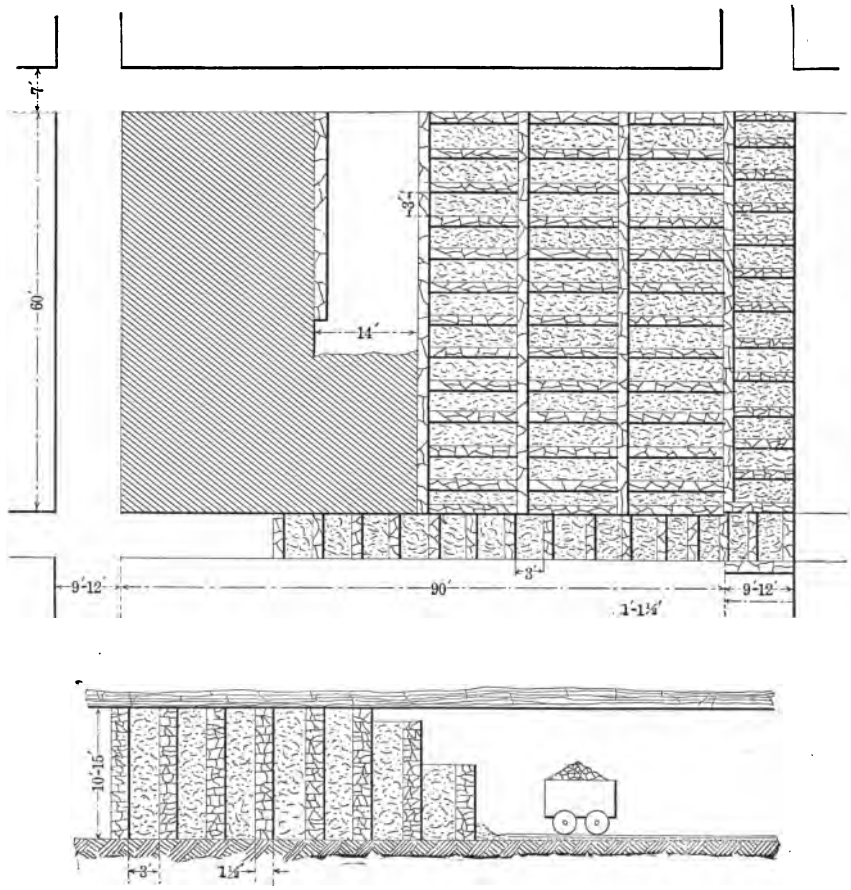


FIG. 56. — Pillar Robbing and Hand Filling.

In building the wall the rock is packed as closely as possible to the roof. As this fine stuff is being placed it is tamped down, with the addition of water. The water is brought down by means of ordinary pipes, but there is not sufficient quantity used to require pumping.

On completion of one lane the next one is started, as in Fig. 56, the walls following up the work. The first operation in attacking a pillar is to pack up the headings.

Pillars are usually cut 20 x 30 yd., the bords 7 ft., and cross-bords, 9 to 12 ft., so that the greatest percentage of ore in the bed is won by the pillar drawing. As a rule, and particularly in this mine, a good many years lapse between the first and second attack of an area. Only continued retimbering will keep the roof intact over wide places, and were the pillars made smaller, precautions would be necessary to avoid "creep."

Pillar Robbing

The ordinary method of robbing the pillars where surface maintenance is not necessary is the same, in general, as at the Spawood mine, *i.e*, dividing the original block, and cutting out sub-blocks with free use of timber, eventually drawing the timber roof supports. It is claimed that at this mine 90 per cent. of the deposit is finally won. A close record of all ore in place, and that hoisted, showed at one time that 93 per cent. was being extracted. With the adoption of the new method of filling, it has been found that a certain amount of surface subsidence has resulted in spite of the precautions taken. This, in one place, has amounted to 15 in., but the management feels satisfied that no serious results will follow if this record is maintained.

When the main haulage-way is approached, entire rows of pillars are left in place on both sides, and it may be advisable to leavé more than one row. However, it is planned before abandoning the mine to remove these pillars. The line of break in the roof is clearly defined on the surface by the relative location of these pillars underground.

In one particular part of a neighboring mine, 13 acres of ground stood intact over a 9-ft. seam with little timber support. It had stood for 20 years. Practically all the timber had been removed at the time of working. There was no indication of subsidence, the formation at this point being particularly in favor of roof maintenance. The time came when this area was approached by workings from the Park Pit. When 3 acres of ground had been divested of ore the entire 16 acres came in at once, with the result that several feet of subsidence resulted over the whole area.

Attention was called here to the inadvisability of leaving timber props standing when building stone work about them. Often a timber crib is built around a prop and this crib filled with rock. The impression given is that a very strong structure has been built, and that the prop is being reinforced by the crib, or vice versa.

A crib is often built which cannot be built up sufficiently tight to immediately reinforce the post, for there is a certain amount of settlement which causes this crib to shrink before steadiness has been obtained. As the weight takes effect the prop starts to bend, and the tendency is now for the prop to destroy the pack, and the crib around it; this renders the structure useless.

CHAPTER XIV. — OAKLEY SLATE QUARRIES, NORTH WALES

A Great Underground Slate Quarry. Spectacular Methods of Mining under Apparently Very Dangerous Conditions. Ladders Raised to 120 ft. Hight by Means of Rope, Roof and Walls thus being made Safe.

In the North of Wales are some of the most important slate quarries in the world. The Penryn quarry, where the work is all done open-cast, extends to a depth at present of 1000 ft., and is the largest in the world. This is situated at Bethesda, near Bangor, North Wales. At this quarry there are said to be 3000 workmen who produce 350 tons daily.

For the purpose of investigating a method of underground quarrying, the mines of the Oakley Slate Company were visited. These are situated in a town called Blaenau Festiniog, about 25 miles southwesterly from Llandudno Junction, a seacoast town from which connections are made on the Great Western Railroad.

Blaenau Festiniog (pronounced Blayno Festinyog) is a small town surrounded by precipitous mountains, on a spur of which the quarries are located. These mountains about the quarries are very much disfigured by waste heaps and excavations.

The Oakley quarries are the largest underground quarries in the world. Originally there were three distinct quarries, but now these are amalgamated; a Royal grant was recently issued extending over a period of 18 years. These quarries are called the Lower, Middle and Upper, and communication between them is effected by means of tunnels and drifts. Originally all the mining was by means of open-air quarrying, but now the bulk of the slate is raised from underground workings, approached by a series of inclines. The haulage route through these inclines may not follow a straight course, treacherous ground often making it necessary to deviate therefrom. There are 28 floors from the top of the quarry to the bottom, and the limit of depth of the slate has not been determined.

The dip of the formation averages 30 deg. to the northwest; the cleavage of the slate is about 45 deg. Four main veins supply the formation: the Old vein, which is 80 to 100 ft. thick, the North vein, which is probably 200 ft. thick, but very coarse, and the Back vein, which approaches 50 ft. with a tendency to pinch out entirely; lastly the New vein, which averages about 75 ft. in thickness.

[illegible] veins are thinner veins of chert and whinstone which [illegible] steeper dip than the slate veins. There are numerous meta-

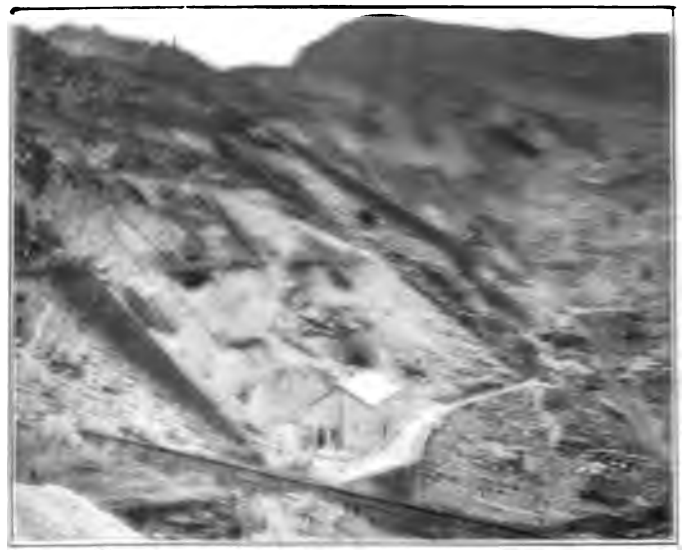


Fig. [illegible] View of Quarries

[illegible] dykes, etc., which show up plainly in the open cuts. [illegible] of the formation may be obtained in Fig. 58, which is a cross-[illegible] through one of the chambers.

a number of small openings where the original underground passages were located.

Method of Mining

The quarry is divided into floors, each of which is designated by a letter (see Fig. 58). These floors are 50 to 60 ft. apart vertically. Coming down the inclines chambers are set off from drifts which run parallel to the strike of the vein. These chambers are 30 to 40 ft. wide, and are separated one from the other by walls 40 ft. wide. The hight of the roof over the floor in any chamber is variable, as the work is carried upward continuously from one level to the next, but the width of chambers remains practically constant. The working is simply a succession of vertical chambers following the dip of the slate, with intervening walls, which extend up to the top of the vein.

Fig. 59. — View at Face in a Chamber.

In starting the chamber, one of which is shown in part in Fig. 59, and in full in Fig. 58, a 4 x 6 ft. drift is first driven up on the hanging wall of the vein from one of the levels. This is continued until the elevation of the level above is met. This drift will follow the dip and be on the center line of a chamber to be. Starting at the bottom, this incline drift is widened right and left, until finally a space 4 ft. high, 30 to 40 ft. wide (the chamber width) and 50 to 60 ft. long is opened. The slate cut in this preliminary opening operation is entirely lost, as is other slate produced in development work.

A free face is now opened at the bottom similarly, as shown in Fig. 58.

Cutting these veins are thinner veins of chert and whinstone which often have a steeper dip than the slate veins. There are numerous meta-

FIG. 57. — View of Quarries.

morphic intrusions, dykes, etc., which show up plainly in the open cuts. An idea of the formation may be obtained in Fig. 58, which is a cross-section through one of the chambers.

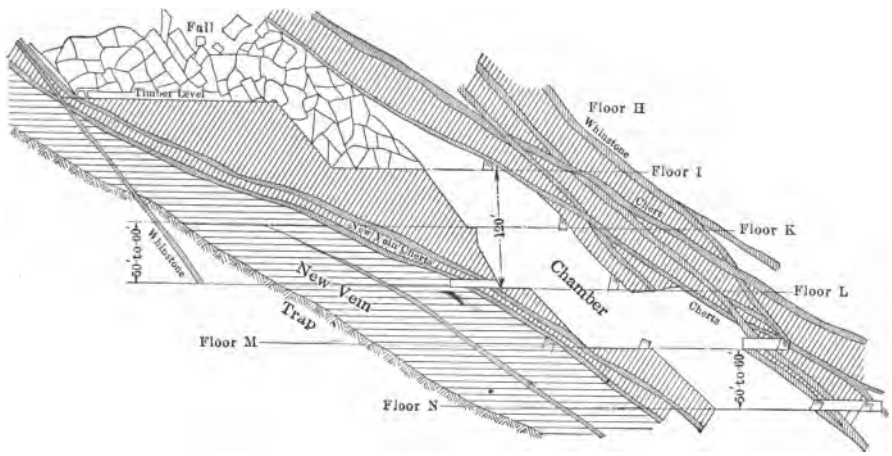


FIG. 58. — Section through a Chamber.

When working full the quarry employs about 1500 men, the output being approximately 6000 tons per month. Fig. 57 is a view of the operations now going on in one of the open quarries. Here may be seen

a number of small openings where the original underground passages were located.

Method of Mining

The quarry is divided into floors, each of which is designated by a letter (see Fig. 58). These floors are 50 to 60 ft. apart vertically. Coming down the inclines chambers are set off from drifts which run parallel to the strike of the vein. These chambers are 30 to 40 ft. wide, and are separated one from the other by walls 40 ft. wide. The hight of the roof over the floor in any chamber is variable, as the work is carried upward continuously from one level to the next, but the width of chambers remains practically constant. The working is simply a succession of vertical chambers following the dip of the slate, with intervening walls, which extend up to the top of the vein.

Fig. 59. — View at Face in a Chamber.

In starting the chamber, one of which is shown in part in Fig. 59, and in full in Fig. 58, a 4 x 6 ft. drift is first driven up on the hanging wall of the vein from one of the levels. This is continued until the elevation of the level above is met. This drift will follow the dip and be on the center line of a chamber to be. Starting at the bottom, this incline drift is widened right and left, until finally a space 4 ft. high, 30 to 40 ft. wide (the chamber width) and 50 to 60 ft. long is opened. The slate cut in this preliminary opening operation is entirely lost, as is other slate produced in development work.

A free face is now opened at the bottom similarly, as shown in Fig. 58.

For this purpose an Ingersoll-Rand bar channeler is used wherever possible. Originally the greater part of this work was done by hand with jumper-drill. The bar-channeler consists of an ordinary Ingersoll air drill set up on a horizontal column along which it may be moved. Holes approximately 2 in. in diameter are bored one next to the other, as shown by the riffles in Fig. 59, and the small partition between the successive holes is finally broken by means of a broad end chisel tool, also operated with the drill. A free face having been formed in this way, large blocks are broken down successively, with the assistance of powder judiciously used, and as this work advances at the various levels of each chamber, a greater hight of back is constantly made over the lower chambers, so that extremely high stopes may be formed, according to the vertical thickness of the vein. In Fig. 58 there is a hight of 120 ft. between floor and roof at one point.

As the extraction of the slate body continues in the various chambers, the original drifts are nullified as the steps advance away from the hanging wall toward the footwall, so that new drifts have to be cut ahead in order to maintain communication with the shaft. Where a floor is kept up, tramming is simply carried on on a track which was formerly enclosed by a drift in the vein, but if the slate on this floor is under attack from a lower floor, the upper bench is subject to undermining, unless all the benches are pushed ahead with the same speed, which is impractical. The time comes when direct communication cannot be maintained from one chamber to another; then run-around drifts are either driven ahead, or a bridge is constructed to cross the intervening gap.

After the chambers have been worked for a while, the area presents the appearance of great cavities 30 to 40 ft. wide between parallel walls 40 ft. thick, which continue successively along the vein perpendicular to its strike. When a chert vein, or other foreign formation, is encountered, quarrying at that point is discontinued. Where such a formation is not of great extent, it may be brought down and the rock hoisted.

The danger due to roof falls appears great; pillar collapses are not infrequent. However, there are few fatal accidents.

The ground under the main inclines must be maintained, and great masses of slate are thus left simply for pillar protection. There has been no means devised whereby the partition walls of slate between the chambers can be recovered.

At each level station there is a side track to the hoisting incline. Each car loaded at the face of a chamber is raised up the incline directly, *i.e.*, there is no re-handling of the load from the time that it is loaded onto the truck at the face, until it reaches the mill on the surface.

Loading and Hoisting the Slate

The men work in squads of four breaking the slate from the vein, and finishing it into slabs in the mills. Where the blocks of slate break larger than can be conveniently handled through the drifts and inclines, the splitting up process is started underground. The large blocks are transported on flat bottom cars which are of distinct design. There are two flanges on the wheel, and the axles extend several inches outside of the hub. The wheels and axles are each free to revolve independently. It is claimed that by this arrangement the heavily loaded cars take sharp curves better than by any other arrangement.

For holding large blocks of slate to the car trucks, chains are bound around the car body and over the block of slate. By means of a plate of iron about 4 in. wide, 6 in. long, and ½ in. thick, with a threaded bolt through one end of the plate, the block is made fast to the car truck. The plate is slid between the chain and the rock which it encircles, and the bolt fed so that a binding effect is produced by the feeding out of the screw.

Water Counterbalance

A means of hoisting in an incline is shown in Fig. 60, the same principle being adopted in a shaft. The scheme consists of balanced skips,

Fig. 60. — Balance Hoisting by Means of Water.

which are set out of balance, where motion is desired, by means of water. Sufficient water is introduced into the tank car at the top to overbalance

the weight to be raised. The speed of the up-trip load with its empty tank is arrested on approaching the top of the incline, by means of a friction clutch operating on the cable, manipulated by a man who also attends to the filling of the tank. On arriving at the bottom of the incline, the tank which has just made its down-trip is drained, being attended by the men who bring up the truck with its load of slate. The same principle is used in a vertical shaft about 100 ft. deep, and the system seems to work well, involving an appreciable saving, in so far that no fuel is required and only the simplest kind of mechanism is required.

Making the Backs Safe

An interesting and important feature is the manner of making these high backs safe to minimize the danger of roof fall in working places. This work is accomplished by means of building up lengths of ladders from floor to roof. Opportunity was had to climb one of the tall ladders to a hight of about 75 ft. The ladder top was not resting against a wall or roof, but was held by means of guide ropes, in much the same manner as a tent pole. While 75 ft. was not the maximum at which these ladders are set, this hight seemed extremely hazardous, especially as I found the men single-jacking from the top of the ladder, which had been built up to within about 2 ft. of the back. These ladders are necessarily of heavy design, and are made of timber, with occasional half-inch tie bolts. The usual length of a section is 30 feet.

The method of building up these sections is to first set up a length against the wall from the floor, and then drill short holes for plugs, the men working at the top of the first length. These plugs are wedged into the wall. To these plugs are attached rings and from these rings are suspended tackles, ropes of which are fastened to the bottom of the next ladder length to be raised. A second section is drawn up by means of tackle fastened above, and its lower end is attached to the top end of the length standing. The two ends are spliced together by means of iron straps and clamps, passing on either side of the rails.

This operation is repeated each time one section is fastened to another. The men immediately climb up the new section, insert plugs into the wall, and by means of the ring and pulley blocks raise another section to be added to the set. The lower plugs serve as anchors for the ropes which hold the ladder set as it is built up, until finally one long ladder has been formed, which, as one, may be moved about the stope by simply loosening one guide rope and taking in another, moving the foot of the ladder with bars as this is being done.

The guide ropes which hold the ladder intact all lead to plugs in the lower portion of the stope, where they can be easily reached and manipulated. To build up a ladder 100 ft. high requires a week's work on the

part of three to six men, and it is only a certain class of men who can be depended upon to do the work safely.

Dressing the Slate

In the mill the blocks of slate are split into pieces of proper size for handling. Finally a second man takes up the rough slabs which have been sliced down to desired thickness and presents the edges to a revolving cutter, which dresses the piece. By means of a right-angled gage, like a carpenter's square, the size of the piece is gaged. The splitting up of the slate, particularly when the pieces attain a moderate thickness, is not so simple as it appears to the layman. It is not always possible in dressing the slate by means of the cutter to produce the desired size, as there is more or less splitting and breaking up. It is this tendency which determines the quality to a certain extent, and affects the cost of production. The slate is cut into standard sizes, known as Queens, Duchesses, Countesses, and Ladies.

PART II

MINING IN GERMANY, FRANCE, AND OTHER COUNTRIES

CHAPTER XV. — LEAD MINING AT MECHERNICH, PRUSSIA

Galena Occurs as Fine Grains in Flat Beds of Sandstone Attaining a Thickness of 75 ft. The Great Deposits are Mined without the Use of Timber.

THE center of the lead-mining operations of the Mechernicher-Bergwerks-Aktien-Vereins is situated in the neighborhood of the town of Mechernich, 34 miles southwest of Cologne, in the province of Rhenish Prussia, Germany. Mechernich is in the heart of a mountainous plateau, the surrounding country being known as the Eifel, a name applied to the district lying between the Moselle, the Rhine and the Roer rivers.

Geologically the strata of the Eifel are Devonian. Lying above are sandstones and conglomerates known as *Bundsandstein*. These are red, green, and white in different horizons. In Mechernich the sandstone particularly, and occasionally the conglomerate, has been impregnated with nodules of galena known as *Knotten*, which might better be called *Knotchen*, for the crystals of galena are generally very small, and are to a certain extent so finely disseminated in the rock as to be invisible.

A typical geological section in one of the mines would be as follows:

Rothes Gorge (red sandstone)	75 meters
Conglomerate	25 meters
Sandstone and Galena	18 meters
Conglomerate	3 meters
Grauwacke	Floor

The ore is usually in appearance a cream to white sandstone of a sugary texture, the grains being apparently independent and well defined. Under a microscope the rock as a whole appears very much like a lump of sugar, except in color. The grains of lead mineral interspersed through the sandstone are also separate; the soft ores may be taken in the hand and crumbled and the lead *Knotten* cleanly separated from the sandstone. The lead mineral is not all visible to the eye. It is estimated that 25 per cent. of the lead contents occurs in the form of disseminated particles, and it is to this material that a large proportion of the extraction losses are due. The extraction of lead is given at 66 per cent.

The Ore Deposits

The seams vary from 4 to 20 m. in thickness, and while dipping at the maximum not much more than 7 deg., often become quite horizontal, thus resembling in certain features the Cambrian limestone lead-bearing formation of southeast Missouri. The Flat River formation is, however, in general much harder and tougher than the Mechernich rock. According to figures given, 1 lb. of explosive breaks 3.25 tons rock. In Mechernich diamond-drill prospecting has not proved successful, the operators being unable to obtain cores. I do not know whether or not the sludge method was tried.

The lead-bearing formation is sharply faulted, as shown in Fig. 65, and the volcanic action which occurred after the deposition of the *Bundsandstein* produced considerable distortion. The strata outcrop strongly on the surface. The faults, which are very steep thrusts, account for the gain in depth of the mining operations.

The overburden is a reddish sandstone which, in general, is soft and is worked off with bucket excavators in open-cast operations. Below this comes the conglomerate, the sands, and the ore. These bands often repeat themselves in certain sections, as many as five veins being worked one below the other. Below the ore-bearing formation lies a rock known as *Grauwacke* which belongs to the lower Devonian, and has the appearance of gray sandstone.

The ore averages between 2 and 3 per cent. lead, the lead carrying 13.14 gram silver per 100 kg. Pockets of copper-bearing rock are sometimes encountered, and small shipments are made monthly. The copper stain is sometimes marked, but the lead ore is usually clean and white, speckled with particles of galena like raisen cake. While in general the ore has little resistance to abrasive action, it seems to stand extremely well under pressure. Occasionally harder sandstones, red and white in color, are encountered.

Method of Mining

The mining operations, which in this district date back to the time of the Romans, have been carried on both by *Tagebau* (open cast) and *Unterirdischgebau* (underground mining). Veins within 150 ft. of the surface are mined by the open-cast method. The two modes of mining supplement each other, the stripping being in all cases disposed of by surface work. The ore is sent down small shafts or chutes connecting the ore horizon of the open cut and underground workings below; and thence hoisted to the surface and distributed to the concentrator. All the ore but that from Callumtherberg and Gute Hoffnung finds its way to *Förderturm* (hoisting shaft) Schafsberg.

There are five mines in operation, three having both open-cast and

underground workings, and the other two underground only. These properties are known as follows: Schafsberg, Unterirdisch, Tagebau

FIG. 61. — Main Shaft House and Open Pit.

Bachrevier, Tagebau Virginia, Unterirdisch Virginia, Neu Schunk Olligschlager, Tagebau Callumtherberg, Unterirdisch Callumtherberg, and Unterirdisch Gute Hoffnung.

FIG. 62. — Open Pit — Concentrator in the Distance.

During my visit, about 1600 men were employed, 558 underground, mining 2000 tons of ore daily, or 3.58 tones per man. The daily pay averages about four marks for eight hours' work for the underground men, and for ten hours for surface men. It appears that the higher wages paid

in Essen and Dusseldorf attract the men there, so that there has been more or less difficulty at Mechernich in obtaining labor. The tonnage produced in the Mechernich lead mines has been greatly reduced; the mines formerly turned out 3500 tons per day.

In open-cast mining it is estimated that three tons of overburden are removed per ton of ore won. As the open-cut work widens, the ore is opened at the bottom of the excavation. When a depth of 150 ft. has been attained, open-cast operations cease, and the work is carried on by underground methods.

The bucket excavators running on three tracks remove the overburden at the rate of 1000 to 3000 cu.m. per 10 hours. Light steam locomotives haul side-dump all-steel cars of 1 cu.m. capacity. From the Callumtherberg mine to Schafsberg the ore is hauled in trains on the surface by means of a steam-storage locomotive, the steam being charged into the boiler under a pressure of eight atmospheres. The capacity is sufficient to make the return trip of 6 km. from Callumtherberg to Schafsberg. The engine is rated at 128 h.p. capacity.

The methods of underground mining employed by the Mechernich company, involves three distinct kinds of work: (1) square work and caving; (2) pillar robbing, as carried on in old workings, Fig. 65; (3) square work and pillar robbing in conjunction with sand filling, as carried on in Gute Hoffnung.

In the first method drifts are extended laterally in the bottom of the seam until a fault plane is encountered, from which point stoping is begun. Drilling is done by air power, hand hammer, or jumper drilling. The average advance for a 2 x 2 m. drift is 60 m. per month with power drills, in three shifts, for six days; 40 m. per month is given as an average for hand drilling.

The use of air drills in this rock is in interesting contrast to the use of the hand rotary drill in the harder rocks of the Cleveland district, England; the policy in both instances appears open to question.

The method of mining is shown in Figs. 63 and 64. Drifts *a a* (Fig. 63) are driven approximately 2 m. square at intervals of 8 to 10 m., and cross-drives *b b*, of similar dimensions, connect these parallel drifts. These cross-drives are shown driven at an angle of 45 deg. to the main drives; this feature is dependent on the grade; where a horizontal formation is met cross-drives will be 90 deg. to the main drives, also at intervals of 10 m. This work of blocking out pillars is done entirely in the lower two meters of a seam the entire thickness of which is perhaps 20 meters.

In Fig. 64 a similar condition is shown, only here the second stage of the work, winning the ore, is in progress.

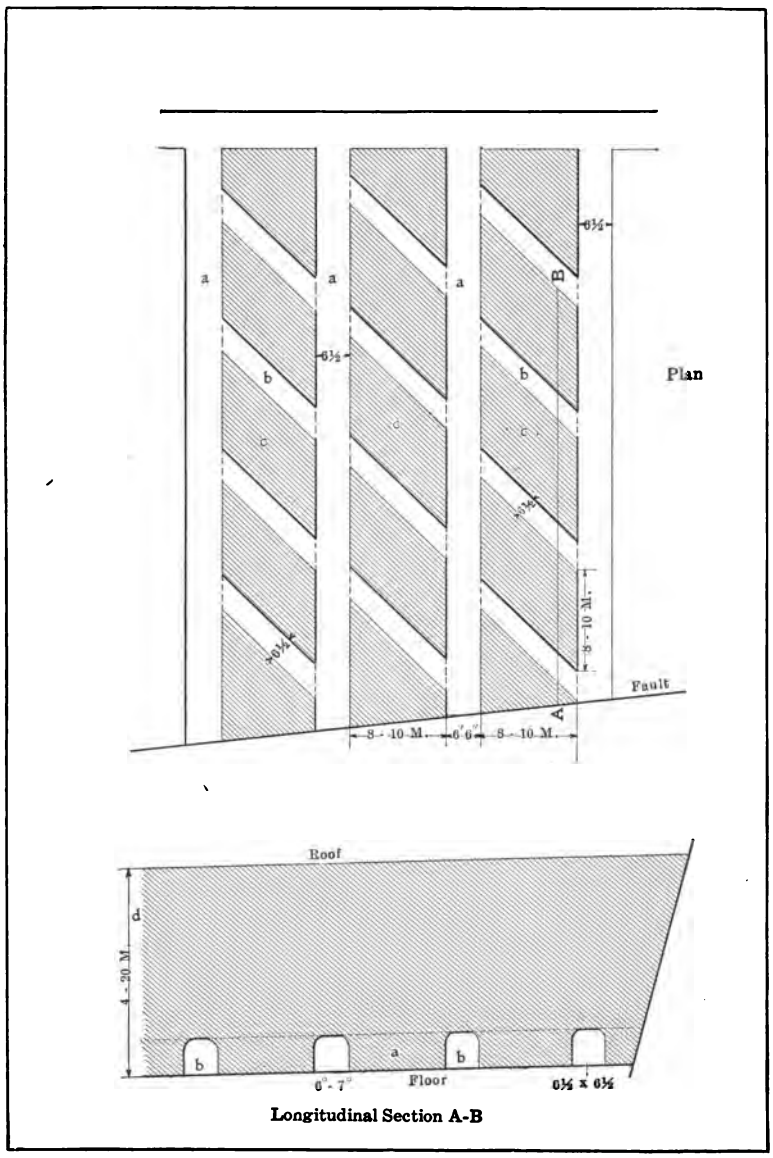


FIG. 63. — Blocking out Pillars in Preparation for Caving Thick Seam.

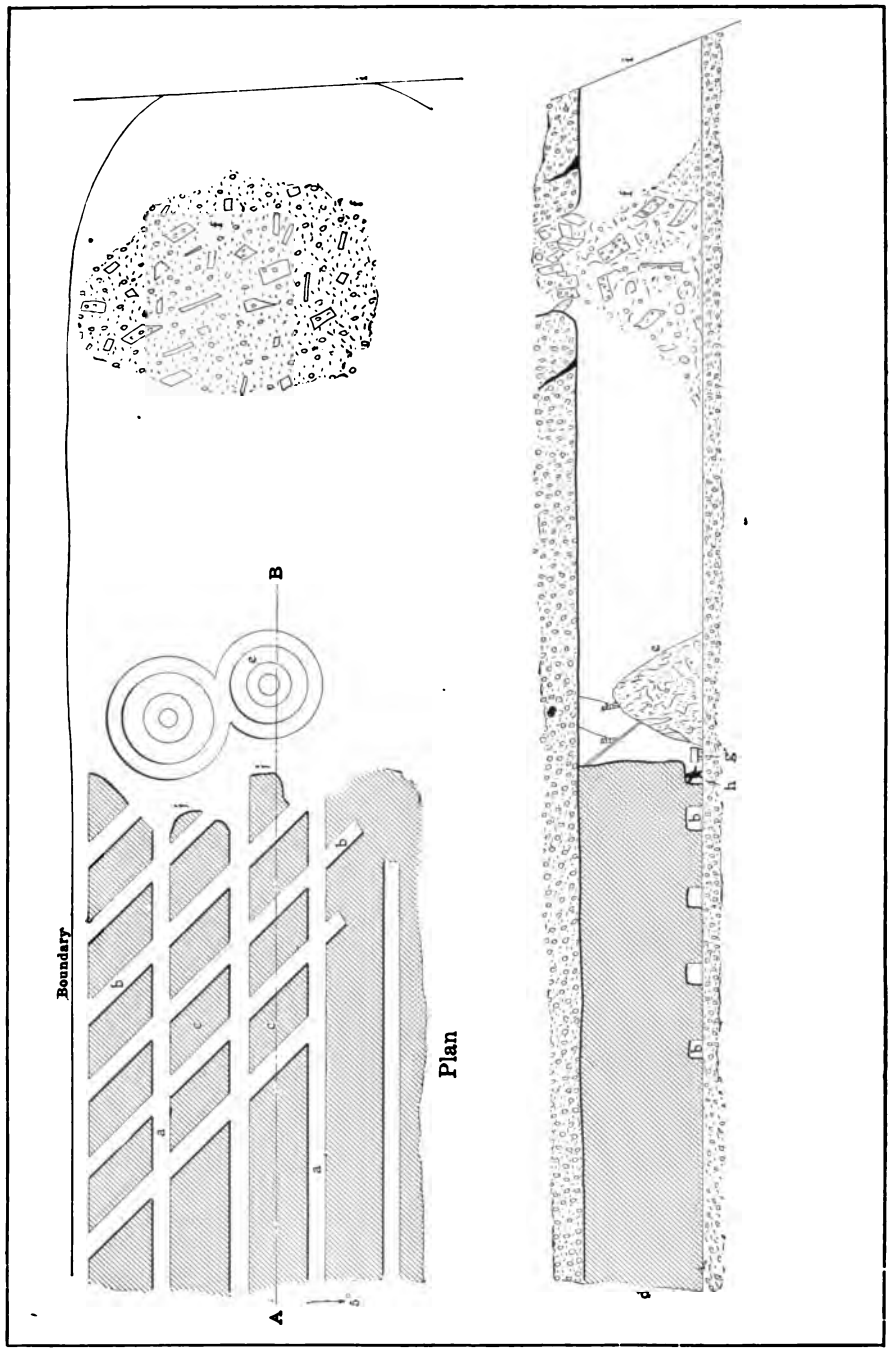


FIG. 64. — Caving the Thick Seam.

Stoping

When the main drives have encountered a fault (Fig. 69) the drifting is discontinued; by this time the blocking out of the pillars by the cross-drives has already made considerable progress. The cross-drives having blocked out the pillars nearest the fault, the work of bringing down the upper part of the seam is now commenced. The manner of attacking the pillars in the lower part of the seam is a development of long experience. In the early days *Sicher Pfeilern* (pillars of safety) were left. At that time these pillars were not disturbed, as shown in the plan of the old workings, the pillars being left with more or less regularity. To-day, however, the extraction of orebodies is as complete as may be expected.

The rock for the most part is soft and friable, although under uniform and constant pressure it is remarkably firm. The ground is much cut up with slips and horses, which are not favorable to safe mining. In spite of this, no timber is used whatever, even for temporary support. The only wood seen in the caving operations, in the methods here described, are for ladders and the long poles used in cleaning the high back and bringing down loose rock.

In attacking the two-meter pillars which are sliced out in order that the overlying rock may cave, undercutting may be begun on all sides, but usually the work is advanced on three sides in the direction of the retreat. As an overhang is produced, this rock is immediately attacked, every endeavor being made to cave everything above the area of the undercut. If this ground does not cave without forcing, the men first test it with poles before proceeding with the work of bringing it down by means of explosives. If drilling is to be done well up in the face and sufficient hight cannot be made by standing on the broken ore piled up from a previous fall, the men drill from ladders, jumper or hammer drills being then used. A stump of pillar is sometimes left to insure a firm support for the roof to aid the work of cutting an adjacent pillar. The men constantly test the roof and make it safe by means of the ladders and poles fitted at one end with iron shoes.

As shown in Fig. 64, the ore has been piled up at *e*, and the men are barring down irregularities in the roof. At *g* is a car into which the men shovel the ore provided that the roof overhead is sufficiently safe. At *h* is a machine drill operating on the pillar. The pile of ore, *e*, is not entirely withdrawn until it is certain that no further testing of the roof at this point is necessary. This artificial method of obtaining hight, which may be 50 ft. or more, is part and parcel of the process. The drifts originally extended to the fault *i*, from which stoping has been carried back as seen in the figure. The roof has stood over a large area before the conglomerate fall, *f*, of the main roof occurred. The parting between roof and lead rock is well defined, and there is little mixture of the two.

Wide Unsupported Areas

In one place I saw an unsupported area approximately 40 x 80 m. in extent. In this place, which was not considered extraordinarily large, the hight of roof above the floor was about 30 ft. and there was no sign of an impending roof fall; the men showed no hesitancy in walking about the area, which was being constantly enlarged. The floor all about was perfectly clean, which fact is evidence that the roof had originally been properly brushed and was not scaling off.

When a roof fall is anticipated the men exercise more than usual care. Being trained to the condition, they know at what moment to take refuge in the drifts which are at all times within easy reach. Only the men who are working on the roof are exposed to danger, warning of which is invariably given by the roof itself in the form of falls of pieces of rock.

The walls of the stopes are so formed as not to cause right angles at the intersection of wall and roof, but rather broad arches to prevent shearing. This point is extremely important, and one which, I believe, admits of wider spacing between pillars because the arching effect produced affords better resistance to roof pressure.

The old Gottesegen mine, shown in plan and section in Fig. 65, was worked years ago. The present company was not involved in the original exploitation, but is now engaged in robbing operations. Directly above the uppermost band of ore is a formation called *Taubesandstein*, which lies under the conglomerate cover. Between the two horizons of ore is a band of conglomerate also found as a floor of the lower ore seam. When this mine was worked the two bands of ore were taken as one with the intervening conglomerate band. At present, where this conglomerate becomes too thick, it is left as a floor for the upper seam of ore. When there is sufficient thickness, pillars need not necessarily be left one directly above another.

In this mine pillars attained a hight of more than 75 ft., and the method of robbing is in a measure quite similar to that employed elsewhere by the company. The pillars at the limit of the stope are attacked first, drilling being done mostly in the bottom of the pillar, which may be attacked from all sides. As undercutting proceeds and shots are fired, the rock in the upper part of the pillar is constantly tested and barred down. The entire pillar is not necessarily removed at once, nor are the pillars necessarily attacked one at a time. However, the work is not done without regard to the neighboring pillars to the one under attack. The work on one bears a definite relation to the condition of its neighbors. Perhaps one half of one pillar may be cut while the last stump of a third will be removed, before the part left in the second is taken. In each case the men climb upon the fallen ground and bar the roof to as safe a condition as possible.

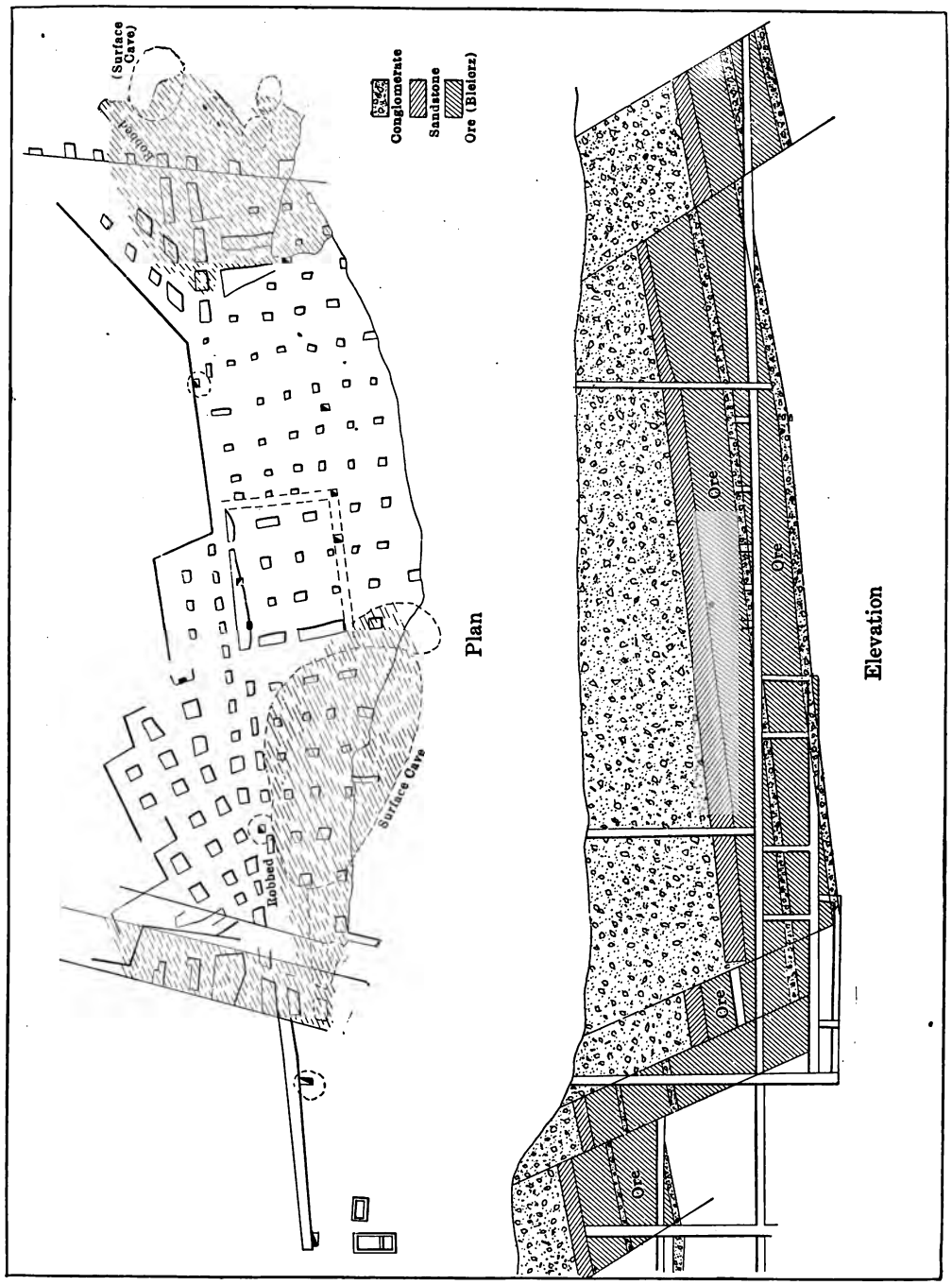


FIG. 65. — Working at Old Gottesegen Mine. Early Method of Working.

The work of removing the pillars, and in fact mining according to the system here described, is a matter of confidence on the part of the men, who work under what appear to be dangerous conditions in the most matter-of-fact way.

The cost of mining in Mechernich was given at 8 to 10 marks per ton of rock, delivered at the top of the shaft. The total cost of producing lead was said to be 24 to 25 marks per 100 kg., equivalent to about 3c. per lb. of lead.

CHAPTER XVI. — THE FLUSHING SYSTEM

A System of Back-filling Workings with Waste. By this Method Mineral may be Recovered which Otherwise would Remain in the Mine as Pillars.

THE practice of back-filling waste material into underground workings by means of water is called "flushing" in America. This idea of so conducting material is of American origin, having been first introduced in Pennsylvania about 17 years ago.

In justice to the originators of the flushing system, it is only fair that a description be first offered of the practice at certain points in Pennsylvania, but it must be admitted that in Europe the practice has received much more attention and use than in America. This applies in Europe to metalliferous mines as well as coal mines.

James B. Davis of the Dodson colliery first worked on the scheme in 1891 at the property of the Dodson Company in Plymouth, Penn., near Wilkesbarre. Up to the year 1907 there had been no decided change in the original method of filling, and the company was still drawing from its waste-culm pile to fill the mine chambers. At the Black Diamond colliery, which was under the management of the Jno. C. Haddock Coal Company, similar operations have been in vogue for some time. The Lehigh Valley Coal Company as well as the Pennsylvania & Reading Coal & Iron Company have not been slow in adopting the idea at a number of points in the State.

Information on the subject does not evince the idea that the flushing system is used elsewhere in the United States than in the State of Pennsylvania. Not many years after the announcement of results at the Dodson colliery, German engineers investigated the field where the process was in successful operation, and have since illustrated their approval of the practice by its universal introduction along most elaborate lines in Germany, where it continues to gain favor constantly.

VALUE OF THE SYSTEM HAS BEEN PROVED

The value of the flushing system as used in Pennsylvania has been proved beyond question. At the Dodson colliery it is questionable whether the property could be successfully worked were it not for filling the excavated areas. This is not alone accountable to the squeeze which was impending, but also to the nature of cover which overlies the thick

seams, and the fact that the coal lies to a great extent directly under the main town. A similar condition existed at Shenandoah City, Penn., where chambers of large extent have been filled to maintain surface structures.

In Upper Silesia, Germany, where the system was first introduced in Europe, and which is to be fully described in following chapters, damage suits were numerous as a result of surface depression caused by the underground excavations. The seams in this field are thick, often attaining 25 ft., consequently the subsidence was severe, and any economic system of mitigating this condition was welcome. The water-filling method has become popular in Silesia because of the extremely favorable results attained with it. Any material in this district (such as gravel, clay, crushed slag, cinders, etc.) which can be moved with water and passed through ordinary sized pipes, is introduced into the workings. Since the adoption of the method, surface damage suits have practically disappeared.

Pillar coal, hitherto unminable because of permanent pillar requirements, is now available, and timber costs have been considerably reduced. Surface troubles have been greatly alleviated, and work underground is now carried on under much safer conditions.

It might be pointed out at the beginning, that the general system as operated in America is rather more with a view of maintaining ground, *i.e.*, reinforcement of the pillars, than as a means of extracting pillar coal which otherwise would be left in place. In Europe, the incipient idea is to effect a complete removal of the deposit; the preliminary layout of the mines is planned with this prospect in view, whether the mining system is pillar work or modified longwall.

Flushing at the Dodson Colliery

Fig. 66 illustrates the general surface arrangements at the Dodson colliery at Plymouth Penn. The culm dump is represented by *a* and shows in the foreground, although much of the material has since been transferred to the mine workings. The old breaker is marked *b*.

The culm dump in the figure is composed of material which was mined many years ago. This contains a good quantity of coal which in former days was not marketable. *C* is the small washery which now rehandles the dump as a whole, and extracts the good product as it is received from the conveyer *D*. This latter is a conveyer of the push-plate type. The trough at *D* in Figs. 66 and 69 shows the chain and push plates leading up to the engine *F*, Fig. 1, at this point the material is directed at right angles to a second conveyer *h* delivering to the washery. The two conveyers measure 680 ft. in length. Fig. 69 shows a section of the conveyer in detail, and the method used for feeding same. The troughs were of

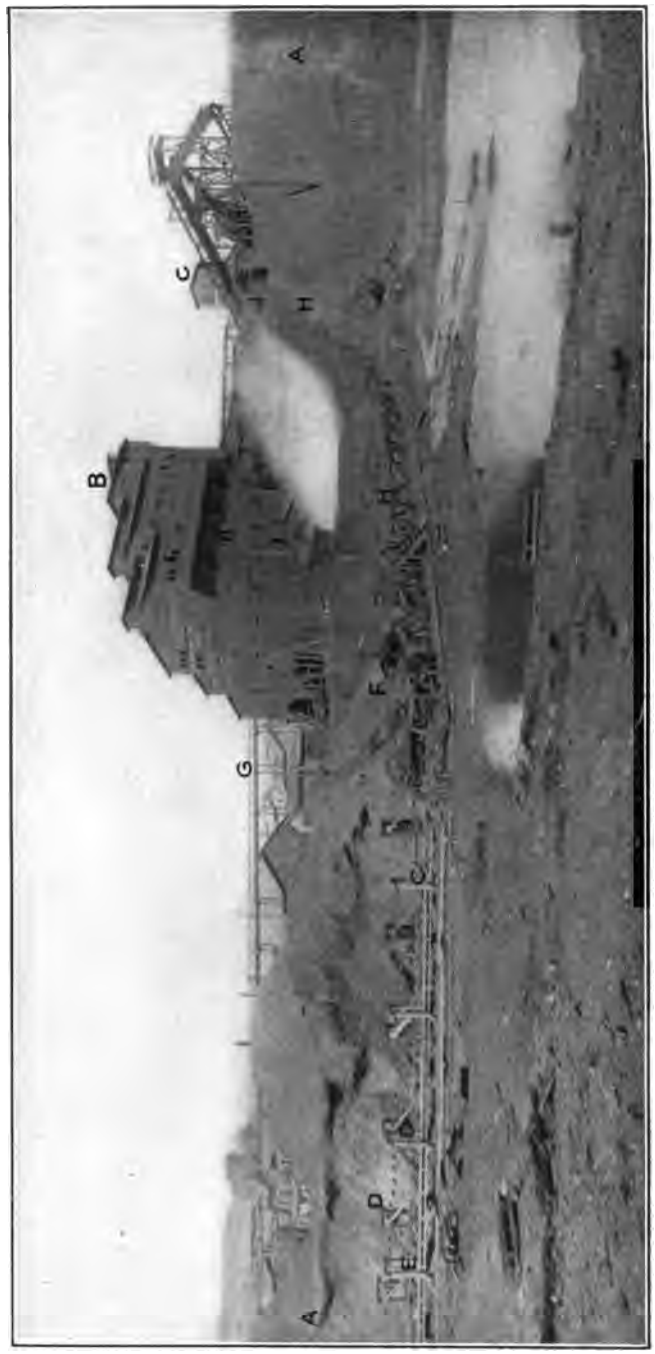


FIG. 66. — Conveying Filling from Culm File.

No. 10 sheet lining in 4-ft. lengths, the shape being half hexagons. The frame sections were 12 ft. in length. As the culm bank is consumed the conveyer is moved up.

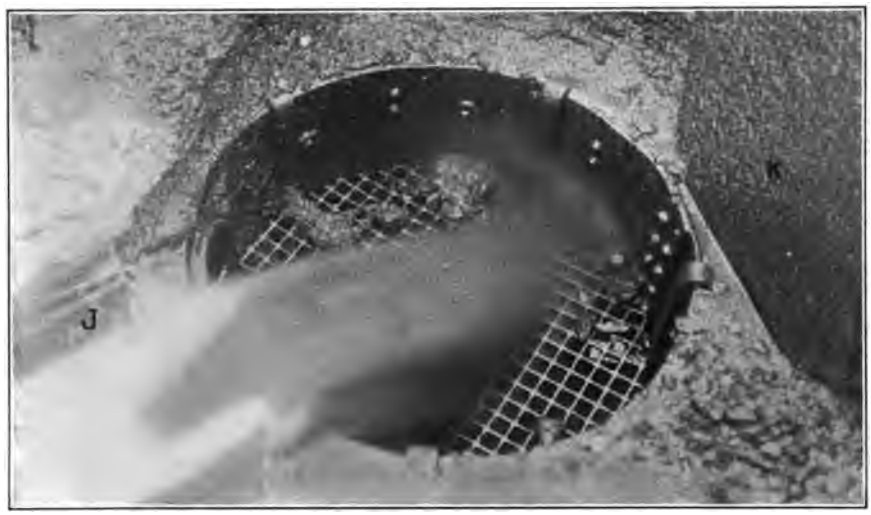


FIG. 67. — Bore-hole Well at Surface Receiving Filling.

At *C*, Fig. 66, the filling is joined by the waste coming from the main washery, and a supply of water, and is thus conducted down the launder *G* of Figs. 66 and 69. The material leaving the washeries will all pass

FIG. 68. — Filling on its Way to Bore-hole.

FIG. 69. — Loading Conveyer.

FIG. 70. — Pipes Entering the Workings at Bore-hole.

through a ⅜-in. ring. The flume is about 650 ft. long and is lined with terra-cotta pipe sections. This flume leads to the bore-hole well, into which the culm may be seen discharging in Fig. 67. Over the hole a tripod is seen. The function of this apparatus is to support rods which are at times brought into play when the hole becomes jammed. The cover which fits over the well casing is marked *k*.

The bore-hole is 8 in. in diameter and 600 ft. in depth; it is lined with 5-in. wrought-iron pipe, the space between the outer periphery of the pipe and the hole being filled with mud. The system of pipe connections underground, where the pipe line starts off from the vertical, is shown in Fig. 70. This is the 360-ft. level. The three valves shown control the direction of flow at this point. Upper valve *L* is a drain cock; if *M* is shut off and *L* opened, a drain of the system is effected. It is important that the system be drained at times when operations cease, or if flushing is to be discontinued at a lower level, and an upper level is to be started. The arm *O* is part of the casting and extending out serves as a bearing against the timber prop, noticed in the illustration.

Pipe Lines Underground

The pipes are laid along the gangways and branch off by means of elbows and tees leading into the mine chambers; 4- and 5-in. pipes are used underground. Experiments were carried on some time ago at the Dodson colliery to test the various pipe materials. It was found that wrought iron gave the best service; that the steel pipe tried was too soft, and that cast iron wore rough inside. At the time of my visit, culm was passing through about 1500 ft. of pipe and there was considerable up-grade in the course of the line. Three hundred and fifty tons of culm was being flushed per 18 hours and the water flow was given at 485 gal. per min., or approximately 5 to 5.5 lb. of water per pound of culm.

The Mine Workings

The Dodson mine comprised seven seams of coal showing a variety of thicknesses ranging from 5 to 23 ft. The method of working was by the bord-and-pillar system though not with the utmost regularity, the pillars necessarily varying in size in different parts of the mine. The seams pitch slightly, although at some points they are quite horizontal. Where there is grade to the workings, the pipe enters the chambers from the upper end, the culm thus banking up to the roof at the lower end, where a barrier has been set to hold the culm intact and allow the water to pass on. Where the floor is level, the pipe is carried into the chamber to its full length, and the discharge end is set close to the roof. As the chamber fills, lengths of pipe are gradually withdrawn. It seems difficult to conceive how a

chamber having a level floor and roof can be completely filled in this way, and it would appear that where a close contact is effected between the filling and the roof it must be due to the bend and settlement of the roof between pillars.

Barriers

Previous to the introduction of the filling into the chambers, the areas are isolated by timber walls which serve to control the inflow of culm. The hight of barriers varies with the thickness of seam. Fig. 70C shows the form generally used. Vertical round posts are set off at 4- to 6-ft. intervals across the mouth of the chamber. These posts are 6 to 12 in. in diameter and are set into hitches previously cut in the floor and roof to receive them.

Where the pitch of the seam is slight, relatively little pressure must be sustained by the barriers, but in the more inclined seams it often becomes necessary to reinforce these posts by additional timbers, or by placing a rock wall on either side of the timber barrier wall. In order to allow the water to drain off from the mass of the culm as it comes to rest, small holes are bored in the planks making up the wall. This same form of barrier may be varied by using round timber throughout instead of plank.

Referring to Fig. 70A, this shows a form of barrier maintained by planks which become imbedded in the filling material; these planks are attached to the barrier wall, and the entire arrangement is self-sustaining. The wall is formed of 2 x 12 in. planks, 12 ft. long, designated by *a* in the figures. Planks *b b* are engaged into this wall at right angles to it, and at a vertical interval of 12 in. The filling backs against the wall *a*, and at the same time accumulates about the *b b* planks. The imbedded planks and the wall are secured by means of 2 x 2 or 2 x 4-in. cleats *c c c*. The wall may be built to any desired hight. The sticks *d d* are simply placed to hold the *b b b* planks apart while the filling accumulates.

The advantage of such a type of barrier is its flexibility, and hitches do not have to be cut in the roof and floor as in the post type. A comparative estimate of cost for the two types, including installation, shows that up to about 8 ft. hight the sectional style is the cheaper of the two. This type of barrier suggests itself as applicable for holding back tailings or culm on the surface.

Fig. 70B illustrates a typical area in the William A mine of the Lehigh Valley Coal Company in Pittston, Pennsylvania. It is noted that the area to be filled is equipped with barriers and that the filling is sent in from the upper gallery. The general method underground is quite the same as at the Dodson colliery. The filling material, culm, came direct from the washery and there was but one lift in the bore-hole. At this lift there was a large L fixture which changed the direction of culm flow from the vertical, and the

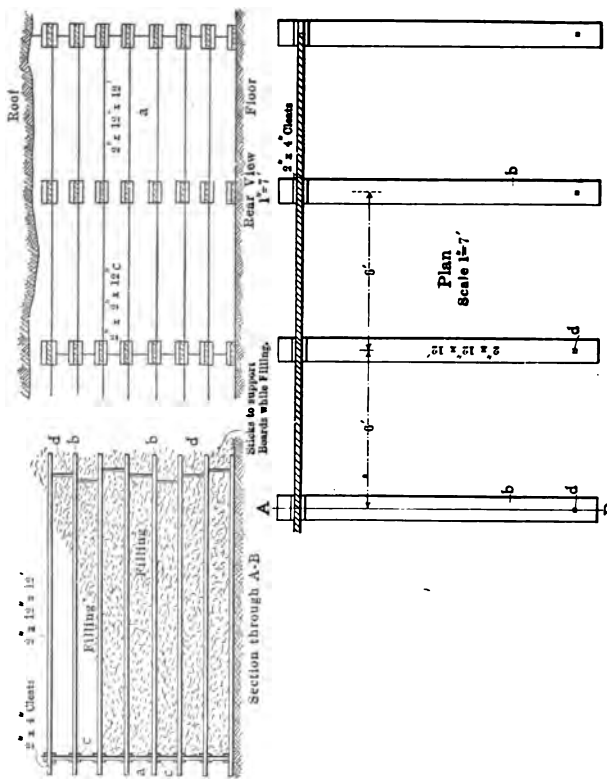


FIG. 70A. — Sectional Timber Barrier Wall Proposed for Use with Filling.

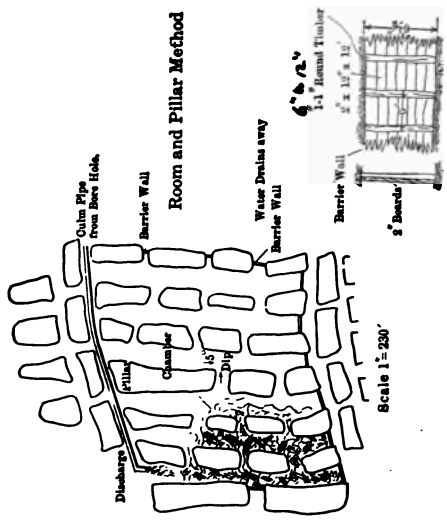


FIG. 70B. — Typical Area in a Flushing Operation in Penn.

FIG. 70C. Barrier Wall.

pipe line was started off at an up-grade so that an accumulation was always present at the L to act as a cushion to the down-flowing stream. The culm particles were considerably larger than the average at Dodson, quite an amount of material as large as 2 in. being noted. This is not unusual, for large-sized gravel is being flushed at another point in the district, where the material is only small enough to pass through a 4-in. pipe.

At the Hazleton No. 2 mine there is arranged an L at the bottom of the bore-hole line, of design shown in Fig. 71. To effect a tight connec-

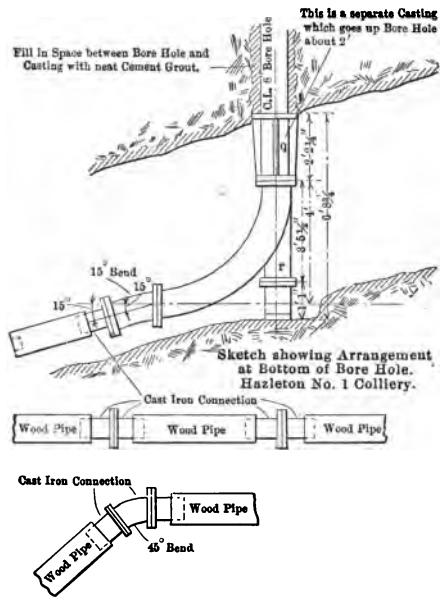

This is a separate Casting which goes up Bore Hole about 2'
Fill in Space between Bore Hole and Casting with neat Cement Grout.
15° Bend
15°
15°
Sketch showing Arrangement at Bottom of Bore Hole. Hazleton No. 1 Colliery.
Cast Iron Connection
Wood Pipe
Wood Pipe
Wood Pipe
Cast Iron Connection
Wood Pipe
45° Bend
Wood Pipe

FIG. 71. — Details of Pipe Connections.
Hazleton No. 1 Colliery.

tion, grout was forced up into the space between the pipe and the walls of the bore-hole. The fixture is supported by a base marked *r*. Wooden pipe of the design shown in Fig. 71 was used at this mine and served well to counteract the corrosive effect of the mine waters on ordinary metal pipes.

EUROPEAN FLUSHING PRACTICE

The Myslowitz colliery at Myslowitz, Upper Silesia, is reputed to be the first European mine to introduce the flushing system known in Germany as "spielversatz." This colliery is one of the larger operations of the foremost German coal-field. The idea of introducing filling with water soon traveled westward and southward, and it was not long before it was practised on an elaborate scale in Westphalia, several districts in France, and also in Austria.

The replacement of coal seams with filling had long been realized a necessity in many parts of Europe, and its introduction became so urgent a requirement that manual labor was pressed into service for the purpose of transferring great volumes of dry material from banks on the surface, and placing it in the mine chambers. In fact, at the present time, in various parts of Europe, dry filling is lowered into mines and shoveled into place behind the coal face; in spite of the expense of hand-loading at the bank and similarly unloading at the face, the practice has been found economical in the long run.

Water flushing is gradually replacing all other methods of filling transference, and it has been universally found that this method far surpasses the dry method from many standpoints, not alone in the matter of manipulative cost, but more particularly in the matter of efficiency.

In using water, the problem of its disposal after having served its purpose as a conductor must not be minimized, and where this water is to be raised from the mine workings, it must be clear to a degree, before being allowed to enter the pumps. These items, in addition to plant requirements on the surface to control the inflow of material as it is brought to the bore hole or shaft, must be considered, in comparing the flushing system with other methods.

Most interesting operations carried on in southern France will be described in detail later on. Suffice it to say that at Carmaux, dry filling has for a long time been practised, but is now being replaced by a successful flushing system, here called "Remblayage par Embouage." The new system has already met with distinct favor, it having been found that the shrinkage in volume of material hydraulically filled is markedly less than where the sand and clay was introduced dry, which, of course, infers amelioration of the objectional surface subsidence feature.

At Carmaux there is a closer connection between the work of introducing the filling and the mining of the coal than at any of the mines in Germany. There the pillars are formed, as a rule, in the regular way, and the filling is introduced in conjunction with robbing operations.

Flushing in Metal Mines

Not alone has flushing been adopted in coal mines of Europe, but in Germany I observed a lead mine where mill tailings were being flushed to great advantage, and at another point, also to be described, an iron mine had introduced a chamber-and-pillar system of mining, in which was involved the flushing of sand, in virtue of which pillar removal was made possible.

I have record of but one mine in England — the Creator Moor Iron mine, herein described, where steps have been made to introduce filling by

flushing, but English engineers are now investigating the Silesian field, with a view of studying the flushing practice there.

Pneumatic Filling

The difficulties involved at times in obtaining water for flushing, as well as the difficulty of its disposal from the workings in a clarified state, has suggested possibilities in the direction of utilizing air under pressure as a motive medium for the stowage material. An experimental plant was recently constructed near Kattowitz, Upper Silesia, to experiment with the idea of introducing filling from the surface to the mine chambers, with compressed air as a conductive force. At the time of my visit in Silesia, during September, 1907, the experiments had not been brought to a conclusion, but sufficient work had been carried on to predict a fair future for the process, in view of the encouraging results thus far attained. This subject is further treated on pages 122 and 123.

It would appear that with any system not involving water, it would be difficult to create a very intimate contact between the particles making up the filling medium. It has been suggested that this involves a condition allowing of excessive shrinkage of the packing and consequent subsidence of the overlying strata.

There will be a great shrinkage in the packed area under roof-weight, as the particles can not be in such intimate contact. On this account the spraying would again be of advantage. It is my opinion, however, that with the pneumatic system less shrinkage is likely than where the stowing is introduced by shoveling, although, unless the air pressure under which the particles are introduced is heavy, the margin may be very small in this regard.

At the Park Pit, Skelton Cumberland, a method previously described of building dry rock walls in certain parts of the mine has been introduced, and within these walls, which are about 1 to 2 ft. thick and built more or less on the pig-stye order, small stuff is packed. The walls are built up to the back, and similarly the loose material is piled up within the skeleton walls. As the loose stuff is placed, sprays of water are added thereto, and the whole tamped as the building up progresses. In this way quite a consistent pack is accomplished, and no more water is introduced than can be absorbed by the filling, so that no water-disposal troubles enter into the problem. The operations on these lines were not very extensive, and were intended merely to counteract surface subsidence at certain points where buildings were located.

At Lens, Pas de Calais, which is in northern France, an inclined seam is back-filled by *remblayage par embouage.* Here, however, the filling material, which is a shale, is lowered to a certain gallery in the mine in cars, where it is dumped into storage receptacles, and on leaving same

comes in contact with water which conducts it to the chambers where the filling is to be introduced. The material at this place attains a maximum of 1 in. in size, and it is said that the ratio of liquid to solid is 4:1. It was found here that a mixture of the shale with sand gave better results as regards consistency and its relation to shrinkage.

CHAPTER XVII. — COAL MINING IN SILESIA

A System is Practised in which Filling is Flushed into the Workings and Total Extraction of Unusually Thick Seams is Accomplished.

SILESIA is the second largest populated province in Germany, being second to Rhenish Prussia. It has about 5,000,000 inhabitants. Breslau, having nearly 500,000 inhabitants, is the second city in Prussia and the seat of government of the province of Silesia. One third of Silesia is governed in turn by Germany, Austria, and Russia.

The area on the east border in the southern extremity of Silesia is known as Ober Schlesien (Upper Silesia). This district is the center of great coal, lead, and zinc operations. Important towns included in this territory are Glerwitz, Labrze, Königshütte, Myslowitz, Kattowitz, Tarnowitz, and Beuthen. The district includes about 1,000,000 people.

At Myslowitz there is what is known as the "Dreikaiserreichsecke," which infers the bordering of three nations, namely, Germany, Russia, and Austria. Germany is on the west shore of a small stream called Prozemessa, which is a stone's throw across. Russian soldiers are stationed on the bridge crossing the stream, and which marks the boundary of the nations. Any attempt to cross this line without passport, which, in addition, has to be renewed monthly in Russia, is met with severe challenge. Only Russia makes the challenges to entrance.

A large number of Russian workmen come into the German territory from Poland, to work in the mines, and these are required to recross the bridge at night before the hour of seven; no one is allowed to enter Russia from a foreign country after that hour.

A great part of the surface work about the mines, such as tramming, shoveling, and washery operations, is done by women; these latter, however, are not allowed underground.

THE COAL SEAMS VARY FROM 14 TO 27 FEET IN THICKNESS

The coal seams which underlie the area from Glerwitz to Myslowitz also extend into Russia, and converge on their approach to the eastward. To the west there are four principal seams; the uppermost of these is known as Einsidel, and is 17 ft. thick; other beds are the Schuckmann, 17 ft.; Heinitz, 14 ft., and the bottom seam, known as Raden, which varies from 23 to 27 ft. thick. The latter seam is a coking coal, the others are gas coals. In Russia the seams unite, becoming two seams each about 33 ft. in thickness.

The average dip of the coal is 10 to 12 deg. The formation is called Sattal Flotze (saddle veins), which name indicates the physical nature of the measures. Geologically, the formation is entirely carboniferous, with intervening rocks of sandstone and schist.

Above the four main seams mentioned, and also below them, are several minor seams which have not yet been worked. The present annual output of the district is about thirty million tons. The demand is met readily from the seams mentioned, and development is well in advance, so that there is no immediate promise of working the lower measures.

To the north, where the triassic formation comes in, and where the dolomite appears, lead and zinc are mined. Germany ranks as the foremost zinc-producing country in the world. Metal mining in Silesia superseded coal mining.

The coal mines are owned by 13 different companies, aside from the enormous holdings of the Prussian government. Permission to enter the Kaiser's mines is not available, except when given by the government. Application for same should be made to the native government of the applicant.

The German spoken in this vicinity is high-class, as compared to the southwestern country, where the dialect is pronounced. English, as in France, is rarely heard outside the cities, and in the country, unless one speaks the language, intercourse is very difficult.

To illustrate the progressiveness of the continental mining industry is cited the following, with a method for testing explosives.

Testing Explosives in Silesia

In a number of the great coal districts of Germany, such as Westphalia, Saarbrüken, and Ober Silesia, the operators are organized, and appropriate support of institutions where experiments of all sorts are carried on which may tend to elevate the industry.

At Beuthen, in Upper Silesia, this idea is well advanced, and experimentation with safety appliances, rescue apparatus in artificially smoke-clouded chambers, and the testing of explosives, are carried on with the utmost care.

For the testing of explosives, a so-called Versuch Stube (experiment chamber) has been constructed. This is an artificial drift approximately 100 ft. long, built elliptical in section, with 8 ft. vertical major axis and 6 ft. minor axis. Three layers of 1 x 3 in. tongue and groove plank, 4 ft. 6 in. long, form the lining; the joints are tarred.

The tube is bound with railroad iron. Only about one quarter of the drift is in daylight, being set in an embankment. At intervals of 3 ft. on the exposed segment are windows 6 x 12 in., of ½-in. plate glass.

These are placed between the hoops of heavy iron which bind the artificial drift. Each of these ports is numbered, beginning at the end where the explosion is effected. At this end, which is slightly higher than the outlet, a heavy hard-steel mortar is set, having a horizontal boring 2½ in. diameter by 18 in. depth. This hole, into which the explosive is charged, points downward to the floor of the drift. Its prolonged axis would intersect the floor 3 ft. distant from the mouth of the hole. All the conditions are made least favorable to explosive manufacturers.

The walls of the drift about the business end are now spread with fine coal dust, a known amount of powder is charged and fired in the mortar, either by fuse or electricity, according to the custom of the district where the explosive is to be used. Atmospheric conditions are noted at the time of each test. The distance traversed by the flash is also noted, according to the number of the last port which the flame is seen to approach. Five charges are usually made in each experiment, and if the dust does not ignite in these attempts, the explosive is declared safe for the particular quantity tried.

A form of explosive composed of 30 per cent. potassium chlorate, and 20 per cent. rosin, was tested. In the first instance, five charges of 500 grams each were tried successfully, and in no case was there ignition. At 600 grams a voluminous flash set up, which could be clearly seen from the point of observation; the observation was made from a small house 75 ft. distant, this house having a narrow panel glass window. A charge of 550 grams gave no flash, and the explosive was declared safe to this extent. The same percentage explosive was again tried, only, in this second instance, the entire rosin ingredient had been treated with nitric acid, whereas the first was only partly so. Two hundred grams threw a flash to No. 9 port, 65 ft. from the point of discharge.

The exhaust of fumes from the drift is readily accomplished after firing by the action of a steam jet, and the experiments thus expeditiously effected.

Deutschland Mine

There are two different methods of mining coal in Upper Silesia: First, the old method of blocking out pillars the entire coal thickness, followed by pillar withdrawal and roof fall; second, a similar preliminary measure, with pillar withdrawal, and replacement.

The work at the Deutschland mine typifies the former method. This mine is located about five miles out of Kattowitz, Upper Silesia, Germany, in a town called Schweintochlowitz. Three thousand tons of coal are mined daily, a good part of which is burned nearby, in the local steel works and for domestic purposes.

The seam here measures about 22 ft., and dips approximately 13 deg. The roof varies from a strong sandstone to a rock called shiebe,

which latter is a hard clay. It is mined in one lift, without replacement of any kind; timber is utilized for temporary support. The timber is eventually withdrawn, marked surface depression ensuing. In the fallen ground, particularly where the pillars have been robbed (this fallen area is called "alter mann"), gas is evolved, containing as much as 8 per cent. CO_2. Certain pillars are necessarily left, in this old Silesian method of mining, to maintain roof in particular areas. In time, these high pillars show signs of crushing, and heat is given off, which renders the conditions dangerous. This method of mining, however, is generally used where filling material is not available.

The similarity to conditions in South Staffordshire, England, are here noticed. The method of mining is distinctly different, and English engineers should be interested in this district.

Method of Mining

Hoisting is done from two levels, 900 ft. and 1400 ft. The method of mining is to block out the coal in the pillars 42 x 75 ft., with a 6-ft. roadway; then starting from the boundary, carry back the pillar-robbing work. This is carried on in steps, on the retreat, and withdrawing the timbers and allowing the roof to come in, is accomplished in a line approximating 45 deg., to the layout of the roads.

On account of the gaseous condition prevalent, similar precautions to those taken at South Staffordshire must be taken here in order to constantly have a supply of good air in the working places; *a* of Fig. 72A shows the dams which set off the "alter mann" (fallen ground) from the coal workings under attack. Approaching the roadway, of Fig. 72B, up to the point where a dam had previously been placed, a leg at *e* was left. The dam is now at *d*, the area beyond that being alter mann. The timbers have been removed, as is indicated by the cross-hatch patching.

The condition we will now assume is a dam standing at *d*, and the work being carried back. Working from *n*, the drift sets which maintain the roadway in the lower 6 ft. of the seam between the legs *a* and *f* are removed and the heavier operation commenced. The small timbers are left, as at *d*, next to the legs *a* and *f* until the very last. A six- to seven-meter face is started at *g*, which includes the original roadway.

The hight that posts are required is measured with a pole. The men standing on ladders hold caps, and the posts are set under. A hole about 8 in. deep is cut in the floor to receive the posts, C of Fig. 72. The posts are all notched to receive the caps, this notch being cut underground.

The timberman first makes a cut about 2½ in. wide and 3 in. deep across the top of a cap, and then trims the edges of this incision to make the whole cut elliptical in form. One side of the cut is made deeper than the other, the high side being marked, so that when the timber is set,

the miners know precisely in which direction to cut the post. Timber is first set under the cap at an inclination, and finally forced into vertical position in a way that the cap rests on the high edge of the post, until the timber eventually takes the overlying weight, when the bearing surface becomes even. In B of Fig. 72, the 7-ft. face, *g*, is carried on till it reaches *h*, when the work is started at *l*, as a face in the other direction, and the coal similarly removed. Finally the leg *f* is standing in a similar manner to *a*.

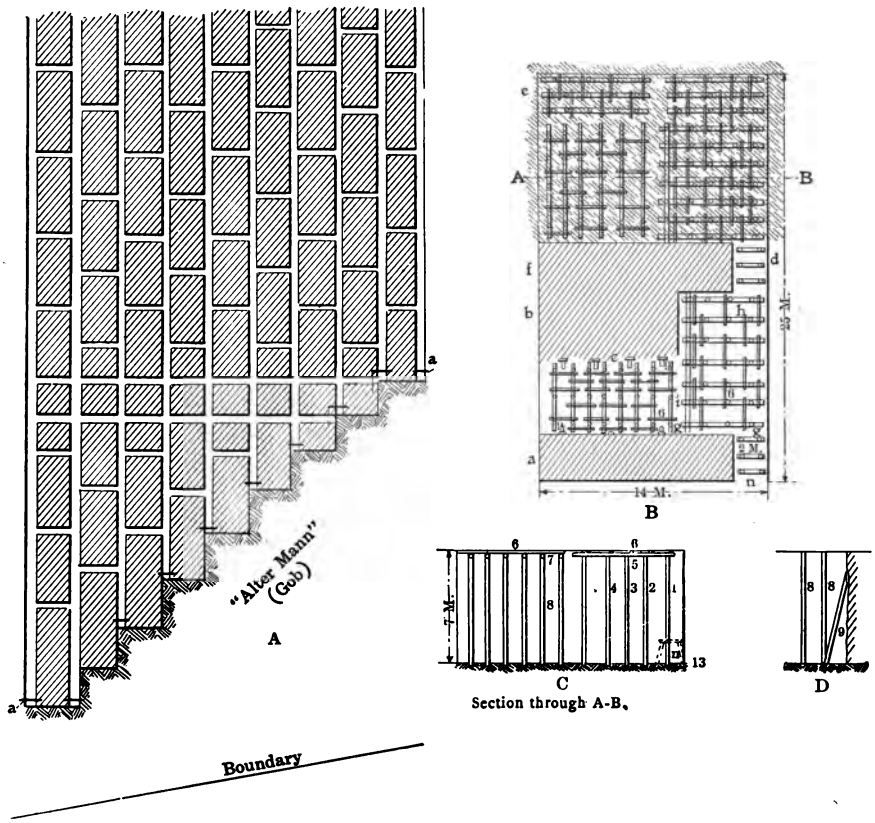


FIG. 72. — General Method of Working the Seam at Deutschland Colliery. Also Detail of Pillar Removal.

The method of getting the coal is by first cutting under, bringing down the overhang by use of powder. At the face, inclined posts 9, 9, 9, are set against the overhang, as shown in *D* of Fig. 72. Just before a shot is to be fired, certain timbers are withdrawn. Over the caps of the vertical timbers, small sticks 6, 6, 6, are set at frequent intervals. Eventually pillar *f* is removed, and all of the timber is drawn from this

area, after which the roof falls, and we have only leg *a* standing. The dam is now placed at *n*, and work is carried on behind, as shown in drawing *A* of Fig. 72.

Dams are formed by setting up poles close together, driving slivers of wood between them, and finally making the dam tight by looting with clay and lime. The dam, it is remembered, is in the 6-ft. hight of original drift.

There are Few Accidents from Falls of Roof

In spite of the fact that there is about 8 per cent. of CaO_2 in the gob, the working area rarely shows more than one half per cent. The system requires careful attention, and from all appearances is dangerous, due to the hight at which the work is carried on. However, I was informed that of the thirteen deaths which occurred during the past year, only four were the result of roof falls, the others being gas fatalities, and due to other causes; this record is far in advance of South Staffordshire.

Fig. 73. — Condition of Chamber, Adjacent Pillar Mined.

As soon as a shot is fired in the face, the men return to the room, scale ladders, and proceed to bring down loose pieces of coal from the back or side. This they do with a long-handled ax, swinging same with one arm and holding the ladder with the other. In changing the position of a ladder, the men do not necessarily descend to the floor, but hobble the ladder about the room from one timber post to the other.

Fig. 73 shows the condition of a room which has been mined in part, with the completely fallen ground close by in the adjacent chamber. The photo was taken in the room where coal cutting was in progress.

Filling Introduced with Air as a Conductive Force

An experimental plant was built near Kattowitz, Upper Silesia, for the purpose of trying out the idea of introducing filling into the mine

workings with air under pressure, as a conductive force. The advantages of such a system are readily seen, in that many difficulties which arise in using water are eliminated. The experiments have not been carried to conclusion, but it is understood in Kattowitz that encouraging results have been obtained, though it appears that sufficient financial backing for the scheme has not been forthcoming. Not alone would water manipulation difficulties underground be done away with, but many mines now lacking a water supply could adopt a mechanical filling method.

The material experimented with was a crushed dolomite, the maximum size being about nut. Pipes were 10 cm. in diameter, and after long experiment it was found best to make the pipe line down the shaft in spiral shape, instead of straight in its vertical course.

It was inferred that the air pressure required was only slight, and that the pipes could be varied in direction at will, without interfering with the system, *i.e.*, made to follow the undulations underground, vertically, or change direction horizontally.

It was learned that considerable dust resulted underground as the result of this method, and that the process as it now stands involves greater expense than water flushing. My own opinion of this process is that the dust difficulty could be obviated by spraying the filled material underground from the time it leaves the pipe mouth. I am inclined to believe in comparing this system with flushing that there will be a greater shrinkage in the packed area under roof-weight, as the particles could not be in such intimate contact. On this account the spraying would again be of advantage.

Myslowitz Colliery

The Myslowitz mine is situated in the Upper Silesian frontier town

Fig. 74.—General View of Myslowitz Colliery.

of Myslowitz, and is one of the great collieries of the district. A general view of this plant is shown in Fig. 74.

Two 18-ft. circular shafts supply 2600 tons of hard steam coal daily

from levels at a depth of 780 and 1100 ft. The thick seam in this mine varies from 28 to 37 ft. There are other seams from 8 to 21 ft. in thickness. Above the coal are stratifications of sandstone and material called schiefer, which is gray in color, and not as strong as the sandstone.

The equipment of this mine is high class. Everywhere the company's consideration for their 2100 employees is noticeable. This attitude of employer toward employee is evident at all mines on the Continent. The change room, for example, is a one-story brick structure, approximately 75 x 100 ft., standing about 35 ft. high. Within, instead of having lockers, the wearing apparel is hung on hooks, which in turn are attached to chains, and in this way the apparel worn in the mines is raised to a skylight in the roof, and a thorough airing made possible. The building is thoroughly equipped with many conveniences for the men.

At the shafts, hoisting cages are of particularly heavy design, being double-deckers, each deck holding four cars. The teeth of the dogs are a series of sharp, curved steel blades. The hoisting rope was 6 cm. in diameter. On the cages there was suspended a metal bell which, when struck, spread alarm throughout the shaft, and attracted attention, at the stations of the shaft, to some disorder on the cage.

For transmission of hoisting signal there was a complete equipment. The system involves the same principle of interchange of signals as in use at Carmaux, and other mines, whereby there was a thorough understanding between the person giving the signal and the hoisting engineer, previous to commencement of winding.

The system of mining by sand replacement was first introduced in Europe at this colliery. The sand, which is a brown material, of fine texture, is quarried from a bank about 20 ft. high and 1500 ft. long, and loaded by means of electrically operated bucket dredges. The quarry is located about a half mile from the mine plant.

The Mine Uses 3000 Tons of Filling Material Daily

This filling material is quite free from dirt. Fig. 75 shows a view of the bank, and the dredge operating same. This dredge is equipped with a 30-h.p. motor, 500 volts direct current. The dredge runs on three tracks. The trolley line is hung on light, steel, lattice-frame poles. These are seen to the right in Fig. 75. The electrical contact to the trolley is effected simply by a bar extending from the dredge, which rests on this wire. This can also be seen in the figure. As the face of the bank advances the trolley poles are moved correspondingly forward.

The upper part of the dredge is equipped with a bin, from which the dump cars, seen in Fig. 76, are loaded. About 3000 tons of this sand is filled into the mine daily (one ton of sand equals 0.77 cu.m.). The dredge can give 3000 cu.m. in 24 hours

FIG. 75. — Sand Dredge Loading Material for Use in Filling.

There has been more or less difficulty, due to the freezing of moisture in the sand. This interfered with the unloading operations. Ordinarily, loading required about 10 seconds per car, and unloading eight seconds. In order to obviate the freezing difficulty, the space between the two legs or braces under the body of the car has been equipped with a grate on which fires are built. In cold weather the bank itself freezes, becoming

FIG. 76. — Filling Hauled to Site of Bore-hole in Dump Cars.

hard, and a similar difficulty was encountered. This is now ameliorated by spreading hot ashes on the surface of the bank where the dredge is operating. At night arc lamps serve for illumination.

In Fig. 76 the traction equipment is shown. Cars are standing over the grating, through which the sand filling passes into the large hopper; this in turn leads to the main pipe line which supplies sand to the underground workings. There is a considerable storage capacity below the grating. At the mouth of the funnel is an arrangement of water sprays, whereby clogging of sand is prevented as it passes down the mouth of the pipe.

These sprays meet the sand under a pressure of eight atmospheres. The water, in being raised from the mine, after draining off from the sand underground and pumped to the surface, is accumulated in sumps. These are located about 50 ft. off to the left of Fig. 76. At this point, electrically driven pumps are operated, and supply the pressure required to keep the pipe line clear.

There are two bore holes supplying the two levels of the mine. Thus the work may be carried on at both elevations simultaneously. This is an advantage over the system used at the Dodson colliery, Plymouth, Penn., where one line intended for two levels could supply only one at a time. Communication was maintained, by means of telephones, between the chambers being filled and the man in charge of the sand-unloading operations at the mouth of the bore-hole.

A large part of the surface work is done by prisoners; such as track laying, and work around the dredge and on the banks. Two thirds of their wage goes to the city, and one third reverts to the prisoner on his release.

It seems difficult to obtain consistent opinions relative to the amount of water required as compared to the volume of sand. It is claimed at Myslowitz that the proportion is 1 to 1, whereas at other quarters this is questioned, it being claimed that the proportion is nearer 2 to 1. The figure in general depends, to an extent, on the horizontal distances through which the filling material has to pass underground, the head, the artificial pressure which may be supplied at the mouth, and the characteristics of the material being flushed.

It is figured that 1 m. of vertical fall affords transport of material over 10 m. horizontal, and 1 atmosphere of pressure is equal to 1 m. of vertical fall, so that an application of eight to ten atmospheres would mean eighty to one hundred meters transport in addition to the pressure head.

As before mentioned, the thickness of coal taken may be as thick as 12 m., and the method in this instance would be to remove same in slices of 6 m. each. The first slice may be taken at 7 m. The work consists in first blocking out the lower slice, by means of headings 2 x 2 m. into squares 10 m. to 12 m. in width, and 12 m. to 14 m. in length, the

long dimension of the pillars being in the direction of dip, which attains 12 deg.

The hard formation overlying the seam, and the dip above mentioned in conjunction with a desirable material for filling, makes this an ideal flushing proposition.

Cost of Pipes Used in Flushing

Sand is conducted to the rooms in pipes of Mannesman steel, which are 178 mm. diameter. The steel is 8 mm. thick, and the pipes are in 6 m. lengths. There is at present in the mine approximately 24,000 ft. of pipe.

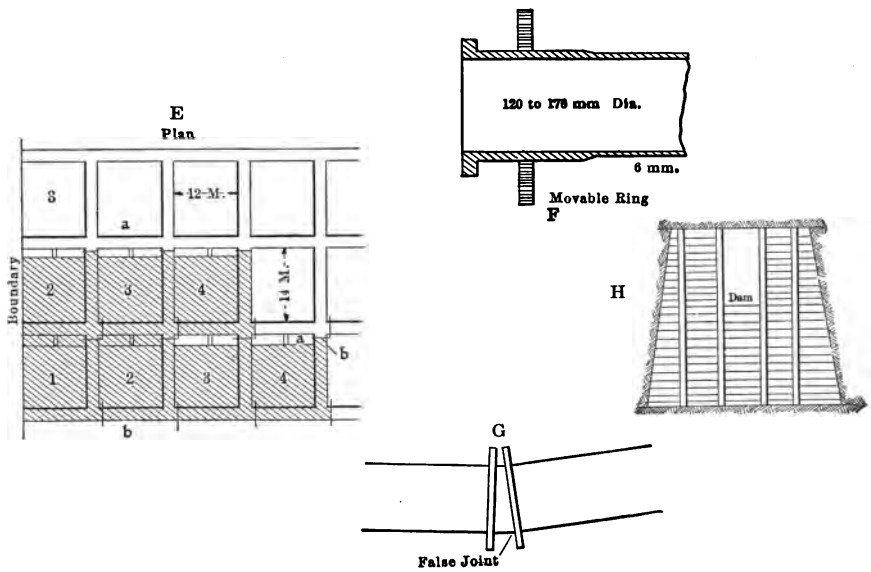


Fig. 77. — Detail of Pipes and Dam. Arrangement of Pillars and Method of Placing Dam in Flushing.

Various materials have been used, but the steel above mentioned has met with the greatest favor. The cost of pipe is given at about $3.25 per m. in France. Along the line of the pipe in the mine, turns are made by means of elbows, which usually have a radius of about 1.25 m. to 1.50 m. The elbows are usually made of cast iron, and wear out rapidly. A piece of sheet iron is held against the worn-out portion of the elbow by means of iron straps. These branches are controlled by means of gate valves, which, at Myslowitz, are of the plunger type. The tendency is to abandon gate valves, and regulate the inflow by branching off, redirecting the flow when one place is filled.

The method of making connections is usually as shown in *F* of Fig. 77, where the end of the pipe has a flange, and movable rings. At this

point on the pipe, reinforcement is often made, as shown. *G* of the same cut shows a slight angle joint. Flanges are held together by means of bolts, which pass through six to eight holes in the rings.

In making connections from the vertical line to the horizontal, it is found advisable to have an angle of at least 130 deg. between an imaginary line connecting the vertical and horizontal directions and the lines of directions themselves.

The lower six or seven meters of the thick seam being blocked out in an area, the pillars are attacked, much in the same way as at the Deutschland mine, where, however, it is remembered, the withdrawal of the timbers is not done in conjunction with filling, but is accompanied by roof falls.

In setting the timbers, plugs are first driven into the roof, and the caps are hung from these plugs with wire, or light rope. Posts are now brought into the room and set under the caps in regular order. Fig. 78 shows the condition of a portion of an area of a pillar where the coal has been replaced by timbers. These posts are set about 2 m. apart. The comparative hight of the roof above the floor can be estimated by observing the man standing on the floor at the right of Fig. 78.

FIG. 78. — Posts and Lattice Roof Timbers in 28-ft. Seam at Myslowitz.

At the upper end of the pillars, legs of protection are left, as at *a*, *a*, *E* of Fig. 77. These legs are finally mined with the main pillar of the next tier above, but not before the sand in the chamber outside it is entirely filled and drained. Before running the flushed sand into the chamber, dams are placed, as seen at *b*, *b*, *b*, which confine the sand. These dams are formed of posts and 2-in. plank, and the structure made tight by means of some packing material, such as straw.

DISTRIBUTION OF THE FILLING

As the mass of filling rises behind the dam, the center boards are set. The chamber being filled, mining is started in the next room, and while

there is more or less coal left standing, in approaching the adjacent filled chamber, it is surprising to see how firmly this sand sets after being allowed to thoroughly drain. The coal shell standing is finally scaled off by the miners in the course of the work, until the filling begins to break in from above, which does not generally occur until practically all the coal has been gotten away.

As seen in Fig. 77 there is an opening left in the legs, the filling pipe usually being brought through this opening. In flushing, the pipe is usually carried to about the center of the chamber, and when the area has been filled up to this point, the pipe is brought back until finally it is set close up to the roof at the head of the chamber.

The sand finds its way into the crevices of the coal in the adjacent pillars, and tends to strengthen same. It requires about three or four days for the water to drain off and the sand then sets in a concrete-like manner. At many points in the mine, a cane could be jabbed into the sand by hand for a few inches only.

Removal of a pillar requires about two shifts of six men; it also requires about sixteen hours to fill such a chamber with sand. It is said that 1 cu.m. of sand is filled for every 1.35 cu.m. of coal mined.

The work in the upper slice is carried on quite similarly to that in the lower slice. There is a certain settlement inevitable in the sand, which, it is claimed, amounts to five or six per cent. of the hight of the area filled. In virtue of this settlement, a certain bending of the upper coal ensues, and it has been found that on account of this, the coal in the upper slice breaks easier than that in the lower.

The floor on which the men work in the upper slice is the sand filling of the lower slice. The track equipment is laid out in the ordinary manner. While this floor is quite hard, the pack is subject to more or less disintegration. In order to avoid a mixture of coal and sand, iron plates are laid on the floor, onto which the coal from the face is dropped.

The water, in draining off from the sand, has more or less solid matter in it, and is quite muddy in appearance. In order to clear this water of the suspended material, drifts are set apart in the lower part of the mine, and are dammed off with concrete masonry. The walls of these concrete dams are countersunk into the floor and hitched into the roof. The drifts may be set off several hundred feet long.

To permit the clarified water to pass the dam, short lengths of 3-in. pipe are set in this wall in a line, one above the other, about 2 ft. apart. The outer ends of these pipe lengths are fitted with stop cocks. Then the elevation from which water shall be permitted to flow off is regulated according to whether this water is clear or not.

The muddy water coming into the reservoir is allowed to rest, and the suspended material settles at the bottom. The clear water is drawn off

by means of these pipes, and passes on to the mine sump. When one of these chambers has been entirely filled with mud, another site is selected, and similarly fitted with a dam.

Flushing at Other Mines in Silesia

Information was obtained relative to operations at various other mines where flushing with water was being carried on, though these mines were not visited. At the Heinitz mine, near Beuthen, cinders, clay, broken bricks, and all kinds of refuse, are flushed down a vertical hole 420 m. deep; the pipe is 182 mm. in diameter.

Before passing into the hole, all the material first goes through a grate having 90-mm. apertures. This material is swept to the hole from a waste heap by means of giants which pass a stream under 30 atmospheres pressure; this pressure is developed by a centrifugal pump.

At the Ferdinand mine, near Kattowitz, where the coal is 2½ m. thick, and dips 25 per cent., city waste is contracted for, for filling purposes. This material is brought to the shaft by 8 h.p. benzine locomotives, which draw dump cars of 1 cu.m. capacity. Sufficient clay and sand are added to make the conglomerate bind. Complete cost of running the above-mentioned locomotive per day is $1.80.

The water supply is pumped from a near-by stream. The dump cars discharge their load into a large hopper-shaped bin, the top of which is equipped with a grating. From this bin the material passes on to a funnel-shaped receptacle, which is connected directly to the main pipe line leading down the shaft; this shaft is 185 ft. in depth. There are two pipe lines, one, a reserve pipe, supported in the shaft at intervals by means of I-beams. Underneath the screen, which is placed in the funnel-shaped receptacle, there is a rising current of water; this screen has 100-mm. apertures.

Underground, a wooden nozzle spout is hung at the end of the pipe line, which permits of readily changing the direction of the inflowing current about the chamber. It is claimed that the cost of filling is about 13 c. per ton. At Myslowitz the cost is said to be somewhat lower than this, figuring closely to 10 c. per ton.

Flushing at the Trinity Colliery

At the Trinity colliery in Austrian Silesia, a mixture of sand, clay, and waste mine rock is effected. The rock is brought to the surface filling plant and crushed. The sand is brought to a separate bin, and dumped by means of an ordinary cylindrical type of dumper. These hopper units are 4 m. apart. The two materials are now led to the main hopper, which connects with the pipe line. This is 220 mm. long; the pipes are 145 mm. in diameter, and 6½ mm. in thickness. This main

hopper is about 790 mm. in diameter at its upper end. At a distance of 450 mm. below the hopper top is a screen, which has square holes of 60 mm. dimensions. This screen is 450 mm. below the top of the funnel. Thirty-five per cent. of the mixture is clay, the other 65 per cent. being sand and broken rock.

In order to facilitate the flushing of this material, there are three 50 mm. branch pipe lines, which emanate from a 145 mm. main conduit. One branch points directly downward, onto the grating in the funnel, and the other two branches pass below the funnel, enter same from below, and afford a rising current against the bottom of the screen.

At the Tielfau colliery in Moravia (Austrian Silesia), up to recently, granulated slag only was conducted into the mine workings. The plant is so arranged that the slag comes either from the smelter works and passes directly down the shaft pipe line, or else passes into a storage bin. This bin, or reservoir, serves in case of stoppages at the smelter works.

Recently binding material in the shape of culm from the coal washery has been intermixed with the slag. The culm and slag is led to the main pipe line by separate hoppers.

Canvass Brattices

At the Deutscher Kaiser colliery, Westphalia, the coal is 5 ft. thick, and dips at 33 per cent. Slag and sand is the filling material there also. An innovation is the use of canvas brattices instead of solid wooden dams, to hold back the filling in the chambers underground. Joists of timber are placed about 12 to 15 cm. apart, against the upright posts, and canvas is stretched over the joists. It has been found that by this method the water which filters through the canvas is clean enough to pass on to the pumps without further settlement. Canvas brattices are also used at Lens Pas de Calais, France.

CHAPTER XVIII. — FLUSHING SYSTEM AT GUTE HOFFNUNG MINE, GERMANY

At this Lead Mine a Shell of Ore is Left as a Roof to Maintain a Treacherous Cover. Tailings are Flushed from the Concentrator into the Chambers.

THE Gute Hoffnung mine, one of the Mechernich Lead Company's properties, is situated in a town called Beschier, near Mechernich, Germany. The ore occurs in flat seams averaging about 6 m. in thickness, and inclined about 5 deg. from the horizontal; the roof is in many places a soft clay formation. Chiefly for this reason a flushing system has been introduced, tailings from the mill being conducted into the workings to replace the pillars.

In general, the method of mining employed is to run 2 x 2 m. drifts in the bottom of the seam, and extending these drifts so as to block out the ground to the limits of the orebody. From these laterals, cross-drifts are driven and pillars 10 x 10 m. square blocked out. Having blocked out a sufficient area the next operation is to bring down the roofs over the drifts to the hight of the seam. This operation is carried on in the drifts around the pillars, so that before robbing is begun, the pillar has been blocked out to the full thickness of the seam. The pillars are then attacked, leaving shells standing temporarily. Dams of timber are arranged in the usual way in the adjoining drift openings, and securely wedged in walls, roof, and floor of the opening. Very often it is necessary to leave a shell of ore 3 or 4 ft. thick for a roof under the clay.

In the work of robbing the pillar, very little timber is used, the pillar being undercut, and everything above brought down as the work advances. A pillar area having been prepared to receive its filling of tailings, a pipe line is extended into the room, as shown in Fig. 79. As the sand and water are flushed into the workings a sort of silt lake is formed, the sand gradually settling to the bottom. In the center of the silt lake is set in a vertical position a piece of perforated tin pipe. The water filtering through these holes is conducted out of the room by means of additional pipe laid on the floor.

As the material enters the pond, a man provided with a hoe gradually builds up a surrounding wall or dam of tailings which holds the water in place until it drains off. As the filling material accumulates in hight, the center pipe is lengthened by means of additional sections.

More or less difficulty has been caused by clogging of the pipe systems, due to the presence of more or less heavy mineral in the tailings. This material often accumulates in the pipe system, and is difficult to dislodge. By placing cocks at intervals in the line it has been found possible to locate the choke more readily. A similar difficulty in France was overcome by reducing the area of the discharge end of pipe.

FIG. 79. — Filling Entering a Chamber Underground and being Held Intact.

The pipe through which the sand passes into the mine is connected with a hopper in the concentrating mill. Tailings are dumped into the hopper soon after they leave the tables in the mill. In the hopper sprays of water, discharging about 50 gal. per minute, flush the material. At the point where the hopper joins the pipe line, a further supply of water, amounting to about 40 gal. per minute, is introduced.

The specific gravity of the material flushed is said to be about 2.8, and the average amount of water used equals 4000 liters per cu.m. of sand flushed, barely one and one half times as much water as sand. The figure given for cost per cu.m. of sand filled is 0.43 marks, or 10.7 c., 3 c. less than the cost of dry back-filling by hand, as formerly practised. The cost therefore is approximately 5 c. per ton of sand flushed.

CHAPTER XIX. — ILSEDE HÜTTE MINE, PEINE, GERMANY*

A Thick, Flat Bed of Iron Ore of Remarkable Regularity and Richness is Completely Extracted. The System of Mining is "Room-pillar," followed by Sand Flushing, the Bed being Attacked, where Thick, in Successive Slices.

THE iron mines of the Ilsede Hütte Company are at a town called Peine, about 20 miles east of the city of Hanover, on the railroad to Brunswick (Braunschweig). Hanover, the capital of the province, is a military city of approximately 250,000 inhabitants, and Brunswick, 33 miles to the westward, has half this number. The mines here described are located in a hamlet called Bülten.

The Ilsede Hütte Company operates two mines, 1.5 miles apart, in this district, Gruber Bülten Adenstadt and Gruber Lengede Bodenstadt. It also operates an iron mine north of Hanover, known as Eiserhaven, and one at Grauhof, in the Harz mountains, the George Friedrich.

At Bülten a coarse conglomerate, *a*, Figs. 80 and 81, contains nodules of limonite, cemented together by calcium phosphate. The ore contains iron, 25 to 45 per cent.; manganese, 3 to 4; phosphorus, 0.6 to 1.4; sulphur, 0.02 to 0.09; and lime, 40 per cent. Directly above the conglomerate is limestone, *b*, followed by a mixture of clay and sand, *c*. Below the conglomerate is a hard clay floor, *d*.

The orebody, from 10 to 12 km. long, and from 3 to 4 km. wide, has a maximum thickness of 20 m. It dips approximately 10 deg. S.E., and strikes N. 45 deg. E. Diamond drill prospecting shows that the thickness diminishes to 1 m. as the end of the deposit is approached to the northward. At this point the deposit is 250 m. below the surface. In Fig. 81, the arrow, *A*, indicates the general direction of the work along the face, *a*, which is carried forward in a straight line for its entire length. At *B*, a train is approaching, which has come from the bench track, shown at *C*, by a circuitous route, and is dumping the overburden behind the face, in the space left by the excavated rock.

Formerly the work at this mine was essentially open-cut, the deposit having a very strong outcrop. Figs. 80 and 81 show also the depth that has been reached. During the past four years a large amount of underground mining has been done, which was necessitated by the thickness of

* Previously published in the Transactions of the *American Institute of Mining Engineers.*

FIG. 80. — Open-cut Method, Showing Method of Stripping the Flat Orebody. a. Coarse Conglomerate Iron-ore. b. Stratified Limestone. c. Clay and Sand.

FIG. 81. — Open-Cut Method, Showing Method of Back-Filling the Stripping. a. Coarse Conglomerate Iron-ore. b. Stratified Limestone. c. Clay and Sand. d. Clay Floor. C. Train Transferring Stripping.

the overburden, due to the dip of the ore below a practically flat surface. Figs. 80 and 81 show that the open-cut work has been carried forward to a point where the mine plant is located, and it is now the intention to remove these structures in order to make way for the mining operation.

At present, the quantity of ore shipped to the furnace per month is 40,000 tons, of which 7000 is mined underground. In course of time all the ore will be extracted by underground operations.

A Regular Orebody

The regularity of the orebody permits of methodical mining, as shown in Fig. 82. A shaft has been sunk to intersect the orebody at a depth of 70 m. When all the ore above this elevation has been mined, other shafts will be sunk beyond this point, and deeper ones. These will tap the ore at the lower elevations it attains with the gradual dip, and each shaft will control a new volume of ore behind it up the rise.

The shaft drift is run out in the direction of strike of the orebody, *B*, Fig. 82, and this drift prolonged about 300 m. At the 300-m. interval an incline, *D*, is started up the rise; and on each side of this incline, through which the ore is carried above to the haulage road, *B*, are man-way inclines, *D'*, *D'*, cut somewhat smaller than the main inclines. At intervals of approximately 16 m. along the inclines, cross- or sub-level drifts, *E*, *E*, *E*, *E*, are run, and pillars, 8 by 16 m., are blocked out from this level. The chambers throughout are about 2 m. high and 3 m. wide. All of this work is on the foot-wall of the bed.

At *C*, Fig. 82, is an auxiliary sump drift, supplying sump, *A*, with clear water, from which level it is raised to the surface by pumps.

Stages of Work

At the point where the bed is 8m. thick the method of work now followed involves two periods of three stages. The first period is the attack on the lower half of the bed. First, the pillars are blocked out. Second, the roof above the drifts, or chambers, is attacked to a certain hight above the hight of the original drift, corresponding to the hight of pillars for this period. (For example, if a thickness of seam is to be worked in two thicknesses, and the drifts, as before mentioned, are 2 m. high, in a 4-m. slice, the roof will be brought down for 2 m. more before the final work of robbing the pillars is commenced.) Third, the pillars are robbed in conjunction with hydraulic sand-filling. When the ground in the lower slice has been entirely robbed and replaced by sand, this sand will be the floor for the operations on the next slice, above, which corresponds to the second period.

The method here followed, as compared with the work in the coal mines at Carmaux, France, is to divest one slice completely and place it

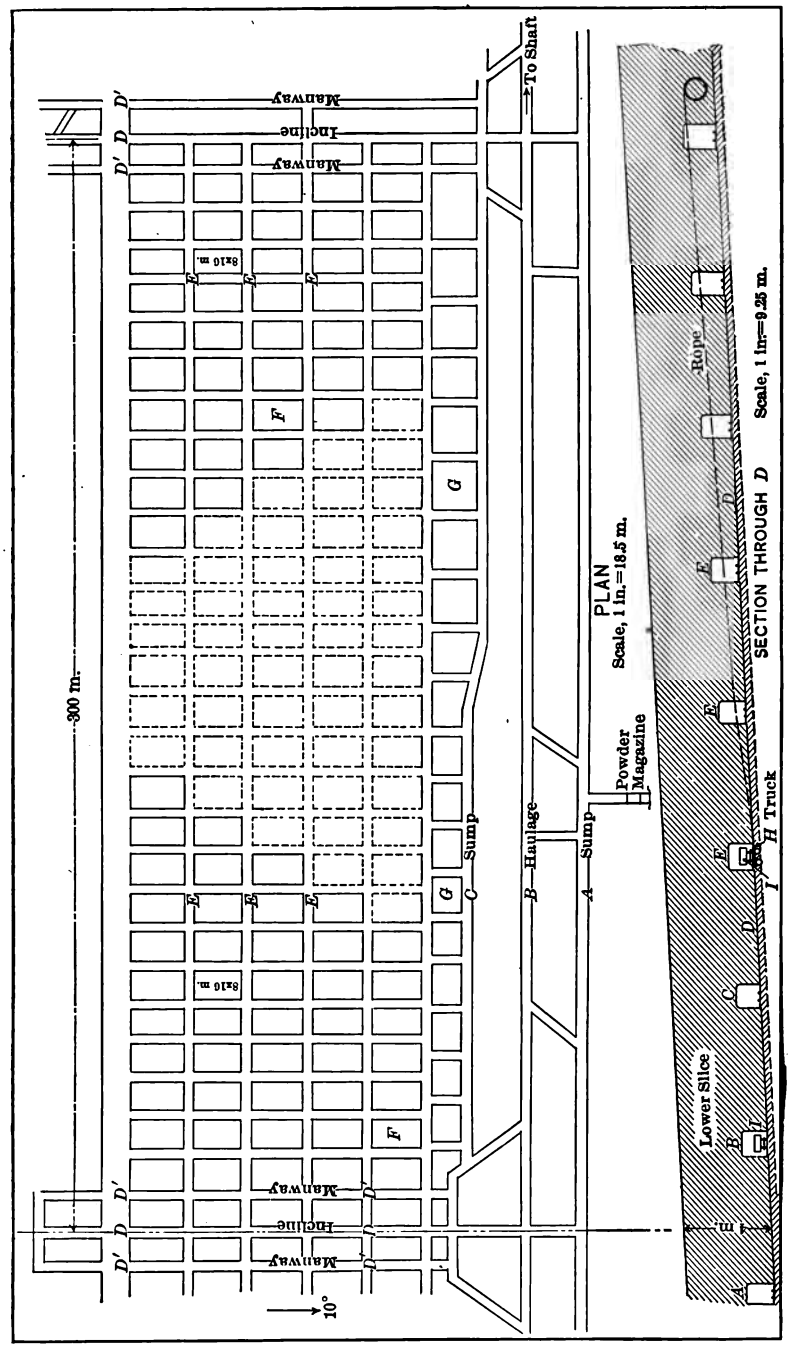


FIG. 82. — Underground Method of Mining same Deposit.

in proper condition for the working of the second slice before actually starting the work on this second slice. At Carmaux several horizontal slices on the same block of ground are worked simultaneously. As indicated in the lower part of Fig. 82, which is a section along one of the inclines, *D*, in the first period the ore is loaded into cars at the lower end of the pillars in each sub-level, *E*, *E*, whence it is trammed past the near man-way, D′, to the incline, *D*. Here the car is run on to a truck, which is hauled up and down the incline by rope traction.

Haulage on Inclines

The inclined truck, which transfers the cars of ore from the sub-levels to the haulage level, has a built-up level platform. When spotted at any sub-level, the cars are pushed on to this platform, the platform track being so fixed as to meet the track of the sub-level. Thus, a car, as shown in Fig. 82, at *I*, passes on to the truck, *H*, and is lowered to the shaft haulage-way, *B*. At this junction the truck enters a depression in the haulage road, and the car of ore is passed off the truck platform and on to the haulage-road track, in the same manner as the car was originally passed on to the truck at the sub-level.

In the main haulage road, electric locomotives gather the cars and conduct the train to the shaft. These locomotives, instead of having trolley poles with a pulley-wheel arrangement at the end, are equipped with wide bar-iron rods in the form of a loop.

Robbing Pillars

The dotted lines, Fig. 82, represent an area which is in the stage of being robbed. The work starts midway between the two inclines. A row of protection pillars, *G*, *G*, 10 m. by 16 m., are left, which are finally removed before abandoning the block. This description applies also to the protection pillars left between the main inclines and the man-ways.

The purpose of having a man-way on either side of the incline is to permit the men working in any block to pass down to the main level without going down an incline in which hoisting is being carried on, or crossing this incline in order to get to an outlet connecting with the main level. The work is started at the center, and there being an incline at either end of the block, the maximum tram at any stage of the operation in a block would not exceed 150 meters.

As before mentioned, the robbing work will not be started until the roof has been brought down in the chambers about the pillars to the maximum hight of the slice. Following the withdrawal of pillars the area is filled.

Filling

The material used for filling is of similar appearance to that used in Upper Silesia, a brown sand which stands very well after the water has drained off. The method of mining the pillars is in certain respects a counterpart of other work in the above district. The filling is brought in from above, being conducted through a bore-hole by the aid of water. Before allowing the sand to enter a chamber, posts are set at about 4-ft. intervals on one side of the chamber and against the wall of the adjacent pillar. Between this wall and the posts is placed 1-in. lagging, with scantlings set a few inches apart, but in no regular manner. This arrangement serves as a brattice to hold the sand intact, so that there will be no mixture with the ore when the work of removing the adjacent pillar is in its last stage. This method is very satisfactory, the pillars being robbed clean up to the sand, which is held vertically intact by the brattice.

The lower openings of the chambers are sealed in the ordinary way with posts and plank, forming a barrier to hold back the sand as it enters the chamber, and allowing the water to drain off. In the robbing work, on reaching the top end of the pillar, a 9-ft. stump is left, which serves as a safeguard, and is removed later on as the methodical work of robbing the pillars progresses.

The water, draining off rapidly from the sand, finds its way to the auxiliary sump, *C*, Fig. 82, though in quite a muddy condition. Here the solution is dammed back until sufficient time has elapsed for the mud to settle, and the water is allowed to pass over the dam and to the main sump, *A*, from which level it is passed on to the sumps.

Comparatively little timber is used in the present work. The roof overhead in the lower slice is ore, and when the lower slice is depleted the upper part of the orebody will rest on the sand of the lower slice. To what extent the conditions will be changed, as regards the amount of timber used, when the upper slice is taken, is interesting, for it appears, from the nature of the beds overlying the ore, *b*, Figs. 81 and 82, that an entirely different nature of roof-rock will have to be dealt with, and that much more timber will be necessary. The breaking of the ore itself, due to settlement, in the upper slice, will probably require less explosive than the quantity used in the lower slices.

CHAPTER XX. — COAL MINES OF CARMAUX, FRANCE

Longwall is Operated in Successive Slices, and the Mined Area Packed with Material Introduced from the Surface. A 12-ft. Seam has been Longwalled in One Slice, which Operation is Extraordinary.

THE town of Carmaux is situated in the department of Le Tarn, southern France. There are about 10,000 inhabitants, who speak a patois not generally understood by the northern Frenchman. There are also a large number of Spaniards throughout this district.

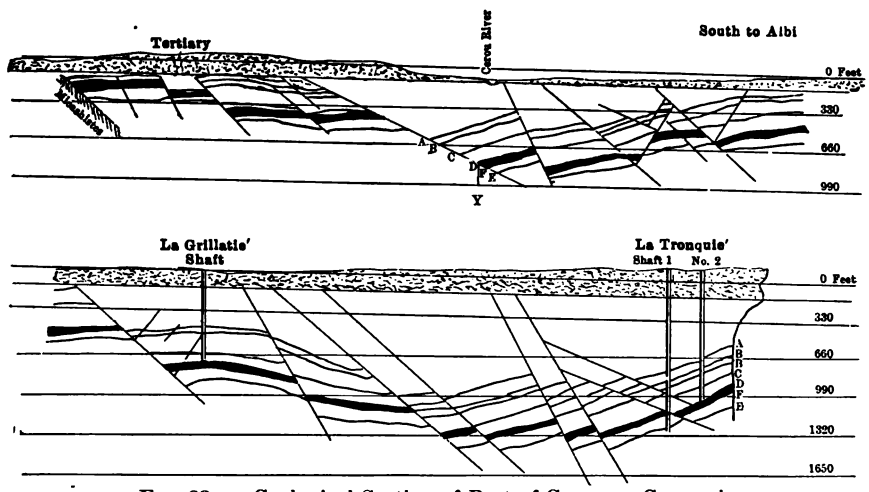


FIG. 83. — Geological Section of Part of Carmaux Concession.

Coal was first mined at Carmaux in 1247. In 1747 privileges were granted to the Marquise de Solages, whose descendants are still in possession of the mines. It was not until 1865, however, that the present company was formed, which is called Compagnie des Mines de Carmaux. In 1906, 1,110,907 tons of coal were produced by the three mines comprising the group. The product involved a gross value for the year of $2,413,146, or $2.17 per ton. The cost of producing was $1,882,576, or $1.69 per ton, and the profit $530,570, or 48c. per ton.

GEOLOGY OF THE FIELD

Fig. 83 is a geological section of a portion of the concession. There are six distinct coal seams. To the north and east, the coal rests on

mica schists and gneisses which limit the coal area. At this point, the seams approach the surface. Schists and sandstones figure largely throughout the entire field, and their bedding with the coal makes elaborate washing operations necessary. The formation is of Permian and Upper Eocene age.

In certain parts, the schistose cover over the seam is of an inconsistent nature, and when exposed to the direct action of the air, on removal of the coal from under, has a propensity to swell, causing roof falls and consequent danger. In France, it appears the precautions taken for the protection of life are greater than elsewhere, and the result is seen in the low fatality record made by the French mines.

Above the coal-bearing formation is a cover of plastic clay and sand, of Tertiary age. This material, which averages about 50 m. in thickness, is excavated with bucket dredges and conducted to the mine openings to completely fill the space left by the coal. The seams are variable in thickness, and while the coal band itself generally attains no greater thickness than 3.80 m., it is generally found necessary to mine the intervening bands of schist and sandstone simultaneously with the coal.

On the Carmaux company's concession there are three main shaft sites, each one having several pits. There are 3250 workmen employed at the mines; 2000 of this number being employed underground.

A peculiar condition exists in this camp, in that the miners are subject to a severe illness, known as "ankylostomiasis," produced by a worm, which, finding its way into the system, permeates the intestines. For a long time it was unknown what produced the illness, until a royal commission finally learned its cause, and now the men take an antidote regularly to counteract the action of the worm.

Shafts and their Equipment

Fig. 84 shows a portion of Sainte Marie No. 1 pit; Fig. 85, La Grillatié, was one of the first plants built. The odd construction of the shaft house is noted in Fig. 85; the head-frame itself is formed of tubular iron.

The two shafts at La Grillatié are 3.50 m., and 2.70 m., respectively, in diameter. There are two levels; one at 168 m., and one at 209 m. One of these shafts is elliptical in form. Two shafts at La Tronquié are 3.50 m. in diameter, while the principal pit of Sainte Marie is 4.10 m., and the second main pit 3.60 m. in diameter.

At Ste. Marie, the filling leaves the cage at 156 m., and the coal is hoisted from the 206-m. level. A number of unique arrangements are installed about these shafts. Timber guides are placed at the long end points of the cages rather than at the sides. A better arrangement of space is aimed at, no room being occupied between the cages for guides. At the shaft mouth, there are no guides for a length of about 3 ft., in order

to allow the cars to pass off the cage. However, the shoes on the cage are always engaged about the guides, at some point, either above or below this 3-ft. space. Where there is an intervening level in the shaft, and this arrangement of having the guides at the end of the cage is used,

FIG. 84. — Sainte Marie No. 1 Pit.

in order to have a continuous track down the shaft, a section of guide is hung on the level gate, which must be closed firmly when hoisting is going on in the shaft past this level.

FIG. 85. — La Grillatié, a Very Old Plant.

Hoisting ropes are flat, and of hemp. They are generally bulky, often weighing as much as 11 kg. per meter of length. The ropes average about 290 mm. wide, and 45 mm. thick. The reason for using hemp rope is not clear to me. I am told that during the first year's life of one

of these ropes, as much as a meter has to be cut off monthly, due to stretch.

Strong safety dogs are used on the cages, but no rope-disengaging device. There is an arrangement on the cages whereby the dogs are held away from the guides while the cage is on the chairs. A rod is fixed between the two dogs, drawing the dogs in, and thus preventing their engagement with the guides. On descending, the rod is disengaged, and the dogs can again assume their proper position.

Ventilation and Lighting

At La Tronquié a multi-cellular centrifugal pump is working under a single lift of 400 m. At both La Grillatié and La Tronquié, Guibal fans of 9 m. diameter are used. At Sainte Marie, a Geueste-Herscher 2-m. fan is used, which is of the exhaust type, making 170 r.p.m., using 90 h.p., and exhausting 37 cu.m. per second, with a depression not exceeding 34 mm. Alternating triphase motors operate these fans.

For lighting purposes in the mine, an odd-shaped oil lamp is used which burns what is known as Colza oil. This lamp is shaped like a canteen, suspended from a U-shaped bracket, to which is linked a small pick. This pick, having a sharp point, is readily engaged in a timber, and the lamp thus suspended.

A mine car prevalently seen in the camp is one formed with angle-iron skeleton frame, the body being closed by boards which are set in this frame.

On the incline, the method of fastening chains to the cars is by means of two hooks, one fastened to the bottom of the car, and another short length of chain, with its hook, leading to the top of the car. It has been found by this arrangement the best balance and control is obtained.

The Cylindrical Dumper

The unloading device on the surface is a mechanically-operated cylindrical dumper. This is shown in Fig. 86. To the right, as shown at *a* in the illustration, a lever encircles the rim of the cylinder. At a short distance above the floor there is a small solid wheel set in the lever bar. There is also a recess notched in the cylinder rim. In Fig. 86 the cylinder has revolved, and the recess has presented itself to the solid wheel. The moment that this small wheel *b* enters the recess the cylinder ceases to turn, for the lever *a*, which controls the mechanism below, causes a disengagement of the motive medium.

When the lever, *a*, Fig. 86, is raised, the wheel, *b*, is withdrawn from the recess, and contact is formed between the cylinder and the revolving mechanism below; the cylinder again is caused to turn, the small solid wheel now riding on the rim of the cylindrical frame, *d*, Fig. 86.

Power is furnished by an electric motor, contact between the revolving mechanism and the cylinder continuing just as long as the wheel rides on the rim, during which time the lever is raised. When the recess again approaches the wheel, the latter enters the same, a complete revolution having been made.

Safety Arrangements

The system of shaft signaling at these mines is an electrical arrangement similar to that used on shipboard, whereby a reply is received by

Fig. 86. — Mechanically Operated Cylindrical Dumps.

means of pointers on a circular dial about 10 in. in diameter. The station tender revolving the signal lever to the order which he wishes to convey, is answered by the hoistman, who goes through a similar operation, causing a second pointer to revolve on the dial from which the original signal was given, thus informing the station tender that all is ready. The station tender now gives the final hoist signal. The Siemens-Schuckert Company, Berlin (formerly Siemens-Halske), are the largest manufacturers of such devices.

A recent invention which has been installed at various large collieries, on recommendation of the government, particularly in Germany, is the Siemens-Ilgner system of safety gears for hoisting engines. By this arrangement, the movement of the throttle is controlled by the position

of the indicator, and the driver is compelled to adhere to the rate of movement of the cage, which has been prescribed for it. The behavior of the cage as it approaches the landing, and all during its flight, is in this way controlled by means of a cam of certain profile, such that the distance through which the driver can move his lever is limited. At the same time the driver is always free to draw back his lever to reduce speed.

A central power plant produces electricity for all the pits of the Carmaux company. Four engines produce 420 h.p. each. The motors are of the Siemens-Halske type; these are tri-phase 50 cycles. The voltage is transformed to 5000 from 240. This plant was completed in 1901.

A modern coke-producing plant is operated in conjunction with the mine. The central washery, built of steel, is located at the same point. The Humboldt system is in operation. Passing through this building, the method of evenly distributing the coal in the bins from above is unique. There is a spiral-shaped metallic launder, about 18 in. wide, standing from the top of the bin to the bottom. The coal slides down this launder and, after coming in contact with the coal below, runs off at a tangent from the spiral conductor and is distributed in the bin.

The coke plant consists of 134 furnaces of the Coppee type; each gives over four tons of coke, after 48 hours' treatment. The furnaces are in groups of eight, and produce two classes of material. One, from 0 to 12 mm. in size, is made into briquets, and 0 to 6 mm. material is used for ordinary coke. After proper coking, the entire block of burned material is shoved off the horizontal shelf in the furnace on whch the coke rests. This is accomplished by a long arm with plate attachment at its end, which butts up against the block of coke and shoves it out of the furnace in its entirety.

Method of Mining

The method of mining at Carmaux is extraordinary, and meets the requirements of the district admirably. Maintenance of the surface is well accomplished, as well as safe working and a high extraction of coal from the area. A modified system of longwall is used in all the seams, and the area mined filled with sand brought from the surface. The mining system might be termed "retreating longwall in panels with complete stowage."

It has been observed in Fig. 83 that the ground is much faulted, which fact figures in the method of mining adopted. The first step in attacking a seam is to follow in the direction of the dip, turning off roads at intervals of approximately 100 m. These roads are continued until the plane of the fault is encountered, when the blocks of coal are laid out and the ground worked on a retreat up-grade. The filling is brought in to replace the coal mined out.

It is endeavored to arrange communication with a shaft so as to allow

sufficient fall for the cars of coal to go out by gravity, and the filling to come in from the quarry in a similar manner, from a higher elevation. Cars of coal coming from the mine are unloaded, and proceed immediately to the point where bucket dredges are mining the filling material; they then return to the mine down the inclines and are emptied at the face. This process is not necessarily continuous. The filling may be brought into the mine at such hours as to suit the work of coal cutting. With a few exceptions, cars in the entire process are moved by gravity force. At La Grillatié, more than a mile is traversed by a car from the time it leaves the face with coal and returns with filling. Here the coal is raised through a shaft and the cars re-enter the mine with the filling through a tunnel.

In Fig. 84, cars are shown returning to the quarry, stopping on the way to be unloaded of the coal. Fig. 87 shows the old method of breaking

FIG. 87. — Old Method of Breaking Down Filling Material.

down the filling material. This work is now done by an electrically operated dredge. According to the topography, the dredge either works as shown in the accompanying illustration, or, in another location, may work against a bank. The dredge buckets are operated by a 30-h.p. motor, the lateral movement of the dredge itself being controlled by a 10-h.p. machine. One hundred and twenty cars of ½-cu.m. capacity are filled per hour. The arm carrying the buckets is manipulated by a 7-h.p. motor.

The longwall system is operated on all the seams, in either one, two, or three slices, according to the thickness of the bed. The method of

filling is either to bring the sand from the quarry dry, dumping and filling the roads at the face by hand, or else, by a system recently introduced, of flushing the sand in with water, building barriers behind the face to hold the sand intact, and allowing the water to drain off. The introduction of the filling is quite the same as previously described. I took occasion to examine a seam 4.5 m. in thickness, and worked in one horizontal slice, with hydraulic filling behind the face. This is the thickest bed of which I have record, where any attempt at the longwall system is made. It is, of course, questionable whether longwall could be operated with such a thickness without complete filling.

The mining of a 6-m. seam was also investigated, where the coal was being taken in two slices, and dry filling replacement introduced. It may be argued also that longwall would not be practical in these seams were it not for the dip of the floor, which makes this method of filling practicable.

The natural grade allows cheap haulage; the water readily drains away, and close packing of the sand is naturally accomplished. A dip of 30 deg. was met at points, but it was not uncommon to see places where the inclination approached close to horizontal.

The system of mining is generally free of dangerous features, although frequent slips of horses in the roof, due to vertical partings, are the cause of occasional accidents.

Fig. 88 shows a system of mining a 2½- to 4-m. seam. Let us assume in Fig. 88, that gallery *Y* is at the lower elevation of the coal seam, a fault having cut the formation at this point. Gallery *X* is at an elevation about 50 ft. above *Y*. Incline *C* has been run to connect *X* and *Y*. Starting at the bottom of the coal, the first cut *o* is made 9 ft. wide, extending approximately 100 m. in length. The gangway *D* is started up the rise to block out the area. The cut *c* is not advanced in one straight sweep, but the face is attacked by means of a cut shown at *u*, Fig. 88, and at *u*, *u*, Fig. 89, these being constantly advanced left and right.

Method of Timbering

In the ordinary longwall, the regular sets of timber are not generally employed; caps are not often used, but simply posts with a top plate, and not always placed with the greatest regularity. Here, however, the form of set shown in Fig. 90 is used, and there is little necessity for the introduction of auxiliary props. When the face has advanced approximately 9 ft., posts *s*, Fig. 89, are set perpendicular to the line of dip. Cap *a* (all figures similarly lettered) is held up temporarily for the post *t*. Prop *t* is cut longer than the vertical distance which it is supposed to occupy. It is cut by machine to the shape shown in Fig. 90, and is set by means of a lever, as shown at *z*, Fig. 89. Post *t* is not set parallel

to post *s*, but with the purpose of counteracting the downward thrust of the roof. As the force acts, the post tends to the vertical, as shown in the dotted lines, and being of excessive length a tight set-up is effected.

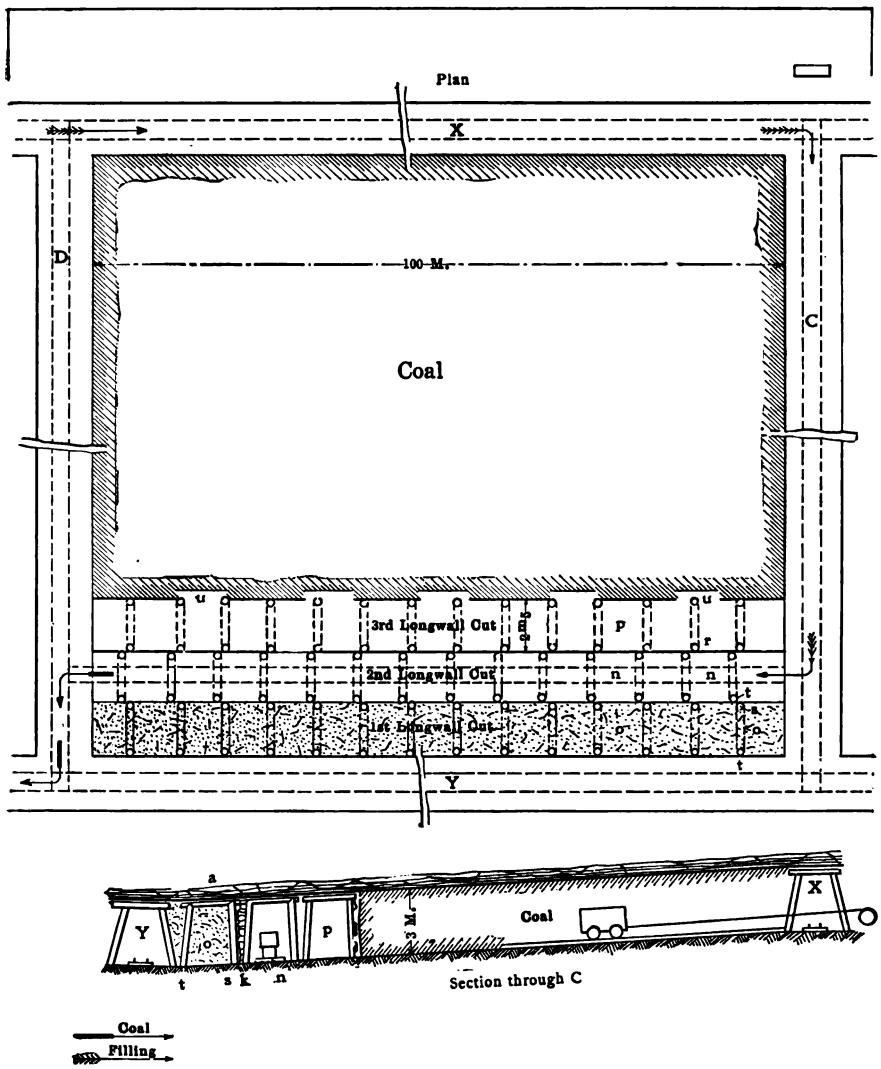


FIG. 88. — General Method of Mining a 2½- to 4-m. Seam.

The track on which the cars run is continuous, back of the face. The latter is constantly advancing, until there is sufficient space ahead for another complete set of timbers, but in the interim the posts may be set up irregularly for safety, until the distance has been made, and a complete

set of timber set up in the regular form. If the face has advanced at one point in a cut-in *u*, timbers are set up to the face at this point.

Note that the caps *a* not alone overlap the post *t*, but often overlap *s* of the post behind, as shown in Fig. 90. Post *s* is set up against the coal face as soon as the distance is made.

The distance between sets along the face varies, according to roof conditions. At certain points, the roof is particularly treacherous, and the coal brittle. In conjunction with this feature is the hight of roof, which makes it more difficult to test, so that extreme caution has to be exercised. At some places, the posts are not more than 4 ft. apart, and

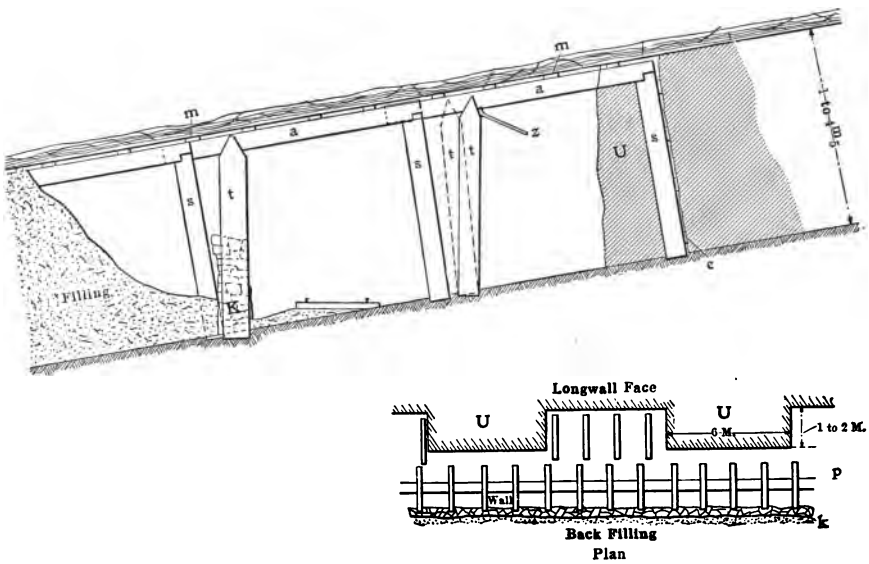


FIG. 89. — Timbering at Face, Filling Operations Follow.

the lagging under the roof hardly more than 2 ft. At such points, the posts *s* were setting closely against the face, lagging was carefully placed between these posts, and the only unprotected part of the face is where the miner draws down coal with his pick. The lagging used at the face is reused, but no other timbers are withdrawn.

Let us consider, in Fig. 88, that the first longwall cut *o* has been completed. Cribs are set at intervals, and stone walls are built, as shown at *k*, in Fig. 89, behind the last row of timbers. This would be the fourth set of timbers behind the face in each case. This operation of building the wall is a regular feature, and part of the system. The purpose of same is to hold the filling intact and away from the track, which track is placed behind the third row of posts.

In Fig. 88 note that the filling will always come down gangway *C*,

and after being dumped behind the face the coal will go out to the shaft in these same cars, going down gangway *D*, along the gallery *Y*, and eventually to the level of the main roadway, communicating with the shaft. When the grades are too steep for hand control of the cars, friction devices are introduced at the head of the inclines. At one point I noticed a brake-car which was set in front of the loads to resist their movement. The controlling mechanism was operated by hand. The

FIG. 90. — Timbering at the Face.

brake-car consisted simply of an ordinary truck, equipped with a strong brake device. This truck, on delivering its loads, was drawn to the top of the grade by horse haulage. In order to arrest the movement of the cars at certain points, specially made dagger-shaped metal sprags with cross-piece were used.

Referring again to Fig. 88, the condition existing is: Longwall cuts No. 1, *o*, and No. 2, *n*, have been completed; No. 3, *p*, is being worked. A sufficient distance has been made in *p* to allow the introduction of sets of timber. The filling is coming in regularly, and the slice *o* is practically filled. The wall *k* runs the complete length of the block. Conditions, as shown, will repeat themselves all the way up one block; one slice will be in the course of being filled, while in the second there will be a track, and in the third the work will be advancing.

Where a seam is too thick to be mined in one division, coal is taken in a number of horizontal slices. A 4½- to 6-m. seam would be mined in 2 lifts, of 2¼ to 3m. each, and a 6- to 10-m. seam in 3 lifts. The interval of working the lifts is usually a year; that is, the mining of an upper slice follows about a year after the coal below has been worked out. However, one slice in a block need not necessarily be completed before the slice above is started.

Mining a 20-ft. Seam

Following is a method of mining a 6-m. seam in two slices of 3m. each. It is remembered that the lower slice is not necessarily all mined out in any one block, but the upper coal is resting on the filling, which has replaced the coal removed in the lower slice. Note that in mining by this system a number of slices are taken, and the cars must eventually gain a certain elevation before reaching the shaft. The gangways leading up to the shaft always remain at the same elevation, but the coal seam itself is attacked at the various elevations of the slices. It is at this point that the complications set in, especially where a number of slices are being operated in the same block. The method of connecting one slice with another, and eventually making the elevation which leads to the shaft, is by means of inclines. The arrangements involve more or less elaborate timbering, and an intelligent arrangement of the work, which will look to economic arrangement and non-delay of operations.

There is a certain amount of settlement which takes place when the slice has been filled, so that all the slices are not removed from their original position. This settlement aids in making connections between the slices. It also plays a very important part in the breaking up of the coal, and renders extraction easier, due to the natural parting of cleavages in the coal.

After about a year with dry filling, a complete settlement is obtained, after which an upper slice is started directly above. It may be that a lower slice is completely removed and filled before an upper one will be begun. Referring to Fig. 91, and noting the characteristics which mark the coal and the filling in each slice, it will be noticed that the lower slice has been mined to within a short distance of the upper gallery X. (The letters F and C, behind the arrows, refer to filling and coal respectively.)

Working the Upper Slice

Starting the upper slice, roads k' and h' (Fig. 91) are run 10 m. to 15 m. from the plane of the corresponding parallel roads, k and h in the lower slice. Road k' is run first, and when reaching a point about midway up the block, a cross-road g is cut across the block. The method of work-

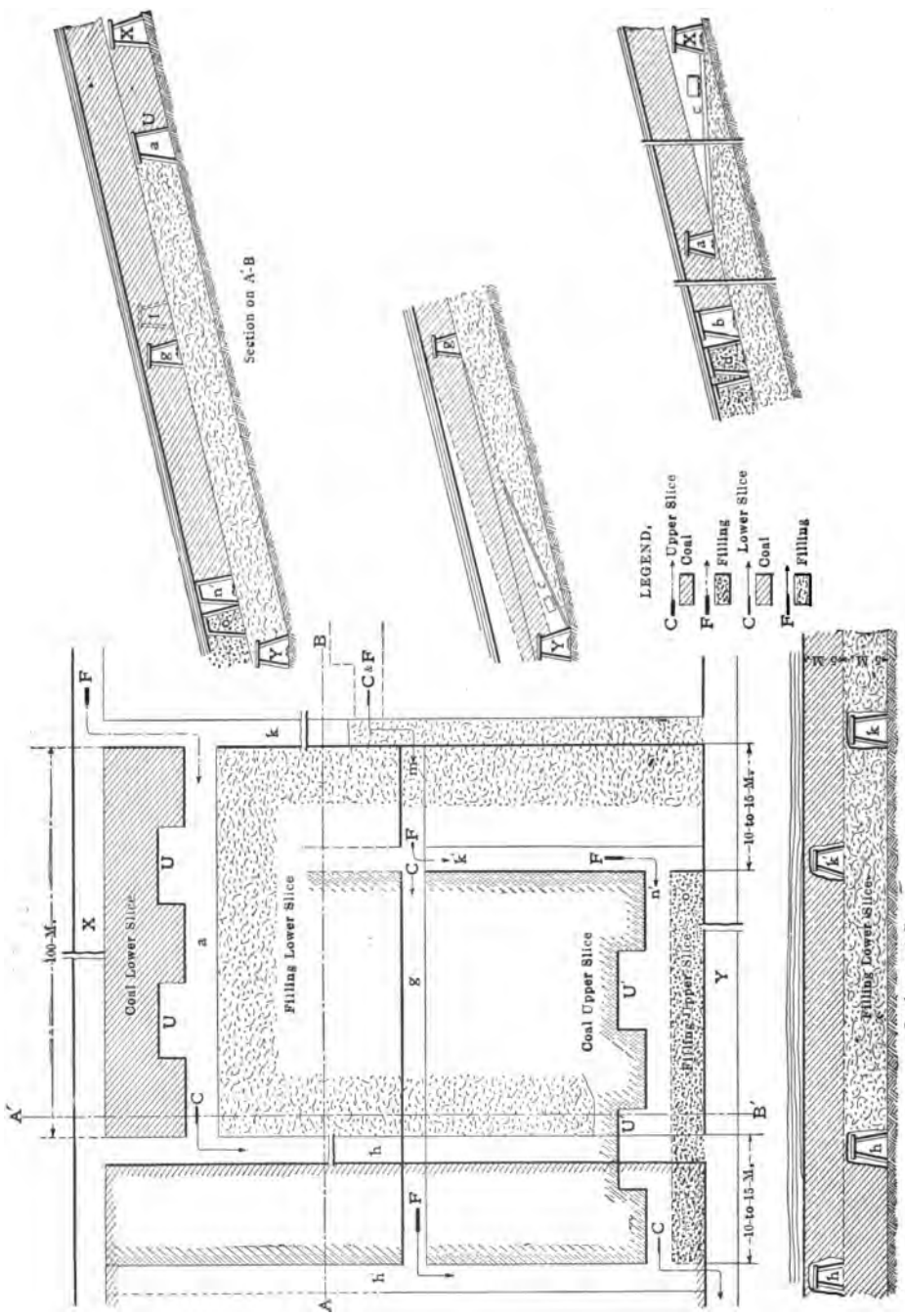


FIG. 91. — General Method of Mining by Two Slices, Showing Scheme of Simultaneously Introducing Filling and Discharging Coal.
C = Coal; F = Filling.

ing the upper coal is quite the same as work in the lower coal; in fact, the working of coal in multiple slices is exactly the same for each slice as if there were to be but one single horizontal cut; the feature lies entirely in making connections, for haulage between the elevations of the various slices, and the main road to the shaft.

It has been noted that the entire output from all the slices, whether two or three, must eventually be hauled out of a main gallery, as Y. Similarly, the filling has to find its way from the main gallery X (which in turn connects with the upper level) to the elevation of the upper slices. Various adjacent blocks of coal may be under fire at the same time, and wherever possible, communication is effected between slices of one block and the slices of another block. This effects economy in the transfer of the filling and the coal.

In Fig. 91 gangway k has been filled up to a certain point, and it can be seen that the filling is coming from an upper slice of an adjacent block l going down gangway g from m and continuing to the incline k', and then to the longwall cut n' to fill o'. Coal is loaded in this road n', in the cars which just brought in the filling, and depart for the gallery Y by means of an incline connecting h' and Y. This arrangement is shown, in exaggerated form by the small section to the right and center of the illustration; the coal here has settled from 30 to 50 per cent., and the filling has all been placed dry.

There is really no occasion for g to be run across the entire block, because the filling for n' goes down the incline k'. Similarly h' need not be run up any further than is necessary to effect communication between n' and gallery Y. However, it is assumed that an adjacent block is being worked, or is to be worked shortly.

In working three slices the system is quite the same, except that the lowest slice will have been completed before the next slice above has been started.

The method of mining here described has been in practice for a long period. With the dry filling, a considerable amount of subsidence on the surface has been felt, in spite of the depth to which mining has been carried on. Recently a system of bringing in the sand with water has been adopted, after exhaustive experiments, both in foreign fields and at the local plant. An experimental plant was first built, and the amount of water required to properly flush the material, also the mechanical arrangements, were tested. The system of water flushing is not in general use yet at all the mines, but wherever it has been used the results have been extremely encouraging from every standpoint.

It has already been noted that the shrinkage in volume of the material filled hydraulically is far less than where the filling has been effected in a dry manner, which naturally means considerably much less subsidence

on the surface. While surface subsidence is not entirely avoided with hydraulic filling, it is found to be hardly noticeable, while with hand filling a distinct depression has always occurred. This work in France has been patterned, to a great extent, after the schemes carried on in the Silesian district.

CHAPTER XXI. — NOTES ON MINING, TIMBERING, AND LIGHTING

In Wales a Machine is Used for Pulling Down the Roof. Some Unusual Methods of Timbering. Carbide Lights used to Great Extent in Europe.

On account of the distances traversed in the coal mines there is little tendency toward compressed-air equipment. In driving tunnels and headings, where the coal seam is not thick and considerable part of the face is hard roof rock, conditions may be no different than those constantly encountered in metal-mining operations.

Statistics on consumption of nitro-glycerin in the coal-mining industry of America point to the fact that hard roofs are not nearly so generally met with as in England. The ground covered in this investigation bears this out. The tendency in coal mines is to use black powder, even in rock work.

Conditions before mentioned have seriously influenced the study of electrically-driven air percussive drills for coal-mining use. The further development in this line is the Siemens & Halske, the type mentioned as being used in the Chopwell colliery. There is a great deal more to be said on the non-success of electrically-driven drills than on their practicability, and, as we know, the only satisfactory air drill in use where electricity is involved underground, is that one in which the electric motor drives an air compressor which in turn supplies the drilling power.

To meet certain conditions there has been introduced in Wales a machine for pulling down top, as is termed the operation of bringing down roof stone over coal in order to make headroom. This is in the form of a hydraulic wedge, and consists of a cylinder 2 to 3 in. in diameter, and about 18 in. long. This cylinder is fitted with plungers along its length. By means of a small hydraulic pump pressure is produced, which forces the plungers outward, the entire cylinder being inserted in a hole drilled for the purpose, or else in a parting in the rock strata. By means of this expansion it is intended that a roof fall be produced. While this mechanism has met with considerable favor in several Welsh collieries, this favoritism may be due to the strong desire to do away with explosives underground wherever possible.

A drawback appears in the drilling of the hole into which the cylinder must be inserted. It is questionable whether, in the long run, any time is saved with this method over the ordinary method in vogue to bring down loose back.

Pit Props

Attention was attracted to a new form of prop or stull, known as the Mannesman weldless pit prop. This form has come into extensive use in various parts of England, Wales, and Germany. Steel props in general have never come into great favor, especially where the repeated use of the same prop was not assured. Where a roof takes weight, the extrication of the artificial support, whether it be steel or timber, is difficult.

In longwall work it has been explained that in order to expect a proper distribution of pressure at the coal face, the fall of roof behind this face should be under control, so that the subsidence be even and gradual. With a rigid steel prop, a bend or break is likely, or else the roof will break around the prop, making it doubtful that the prop itself will be recovered. If the rigid steel prop breaks suddenly, an advantage of timber, which always gives warning when about to fail, is not obtained.

Mannesman weldless props consist of two tubes of Weldless steel, one of which telescopes the other. This telescoping admits of lengthening or shortening the prop at will. A clamp serves to bind the two telescoping tubes when the proper length has been adjusted. The usual manner of setting up these props is to measure the hight they are intended to occupy, and fixing the clamp accordingly. A cap of timber is usually used at the top of the prop, and the column is set very much in the same manner as an ordinary prop., *i.e.*, by holding it in an inclined position and forcing it upright by means of hammer blows at its top. The benefit of this form of prop is that when the load limit (which is placed at 15 tons) has been obtained, instead of buckling, the telescope acts and the prop is gradually shortened.

These props have not been used in England on seams over 7½ ft. in hight, and I question whether the empirical figure of 15 tons will hold good when the prop is used to greater hights. They are made up to hights of 10 ft. 8 in. (when telescope is extended), such a one being 6 ft. 4¼ in. long when closed.

A form of repairing prop is also made on the same principle for use up to 20 ft. (extended). This form differs from the other in that it is fitted at the top with a screw-jack. In replacing posts, a cap or steel girder may be temporarily shored up by means of the repair prop, while the original post is removed. The cost of the ordinary pit prop of this type varies in England from $2.88 for a 2 ft. 8 in. prop, to $5.72 for the 10 ft. 8 in. prop.

Steel Timbering

In Fig. 92, *A* illustrates a method of maintaining drift timber through heavy ground at the Oakley quarries at Blaenau Festiniog, North Wales.

Ground through which one of these roads runs had been found to be very heavy, and it was necessary to reinforce the ordinary timber set, *a*, with a second set, posts of which, *c*, *c*, are lengths of ordinary steel rails about

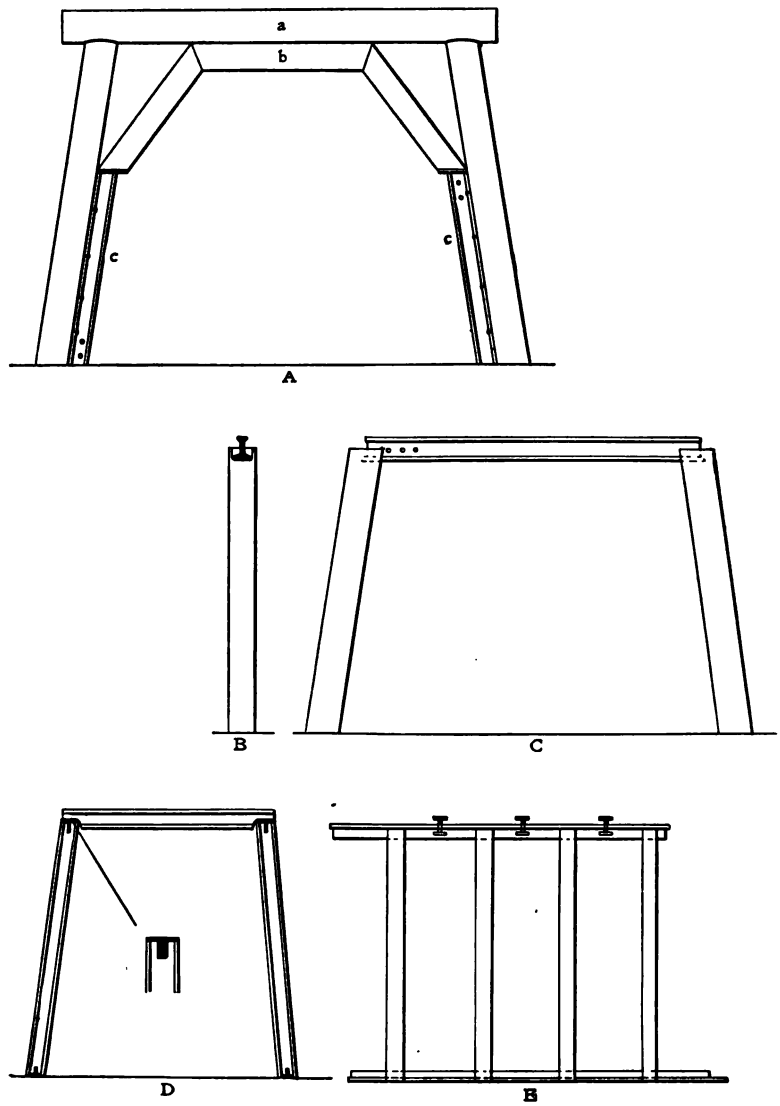


FIG. 92. —Steel Timbering.

4 ft. long. This railroad iron is spiked to the post of the original set, and has been found a very efficient reinforcement.

B and *C* illustrate a form of drift set often seen in England. The caps

are railroad iron, which set in half-way; the ends of posts have been cut to receive same. It would appear that the top of post is subject to splitting.

D and *E* show a complete steel timber drift set used in Germany. The two base pieces, and the stringers which run laterally along the drift, are T bars, while the posts and caps are I-beams.

ILLUMINATION

The use of acetylene underground has met with distinct favor throughout all the European mining districts. Tallow candles and oil are still used to a great extent in working places, but the modern form of acetylene gas lamp is largely used by officials. These lamps, which are made of brass, are very well constructed, and serve most efficiently.

At Mechernich, Germany, arc lamps without glass globes are used underground, and the result has been very favorable. The condition of walls and roof is constantly under clear surveillance. A single lamp illuminates a large area. The cost for operating the arc lamps at Mechernich is given as one mark per 24 hours.

The Wolf Safety Lamp Company, of Leeds, England, is the maker of a well-recommended type of acetylene lamp referred to above. Aside from the type of lamp used for carrying in the hand, a larger stationary model which may be hung at any point is made. It weighs 8 lb. and has a rated lighting effect of 50 candle power; one charge of acetylene affords 14 to 16 hours' light.

All these lamps work on the same principle, and consist of a lower carbide holder containing no joints, but pressed out of one piece of sheet steel or brass. On this lower vessel is fixed the burner. The upper vessel, the water reservoir, is clamped over the lower vessel, the carbide reservoir, by means of a bridle. The degree of light to be emitted from the burner is regulated by the speed of admission of water from the upper to the lower reservoir, where the contact with the carbide is effected and the acetylene gas evolved.

Carbide cost in England, in burning Wolf lamps, is given at $\frac{1}{16}$ penny per hour. At Carmaux, France, the figure given for consumption in this form of lamp was $\frac{1}{2}$ lb. carbide for 10 hours' burning, the carbide costing 70 centimes per kilogram. This figures 6.36 c. per lb. of carbide, or 0.03 c. per hour. Carbide in England, yielding 4.9 cu. ft. of gas per lb. of calcium carbide, sells for $5\frac{1}{2}$ p. per lb. or 11.1 c.; in hundred weight lots, $3\frac{1}{2}$ p. per lb. or 7.09 c.

In using acetylene lamps they should be cleaned each time they are used; this does not amount to more than seeing that the aperture which admits the water to the carbide reservoir is kept open. The evolution of unconsumed gas when not ignited at the burner is disagreeable, and it will

be found well, when turning off the water supply, to keep the gas lit until it ceases to be evolved; in short, to allow itself to burn out.

Three sizes of these lamps which burn 6, 8, to 12 hours, weigh 1 lb. 8 oz., 1 lb. 12 oz., and 1 lb. 14 oz., respectively; they average about 6½ in. in hight, and may be purchased in England for 8 to 10 s. The price of the large stationary lamp before mentioned is £3, 16 s.

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